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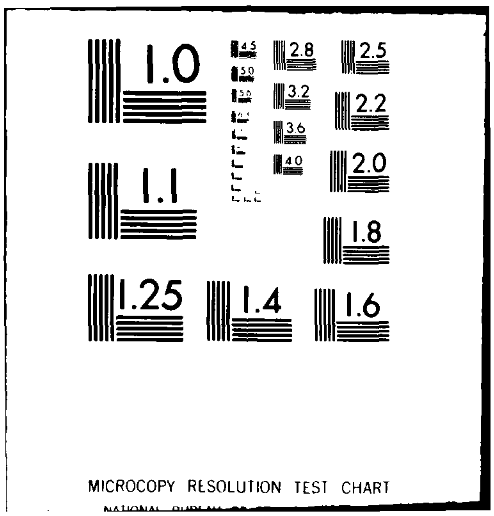
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Technical Report NAVTRAEQUIPCEN 78-C-0129-1

TECHNOLOGY FOR AN EFFICIENT DELIVERY SYSTEM

W. W. Hawkins and H. D. Kribs
Instructional Science and Development, Inc.
5059 Newport Avenue, Suite 303
San Diego, California 92107

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Evolutions in video and computer technology are occurring that may provide more cost- and training-effectiveness than traditional audio visual media. The purpose of the study was to determine the feasibility, specifications, and costs of using such technology for advanced instructional delivery systems.

PREFACE

The Naval Training Equipment Center has been responsible for the technical direction of a series of efforts aimed at developing improved fleet aviation training systems. The implementation of an Instructional Systems Development (ISD) methodology has been a primary development of these efforts. The methodology has proven to be both training- and cost-effective.

A large percentage of ISD resources is spent on the development and delivery of instructional materials. An opportunity to significantly reduce the amount spent on these two phases of curriculum development is afforded by recent technological developments in video playback and microprocessor technologies. In particular, the microcomputer-controlled optical videodisc holds a tremendous potential as an instructional media in a large number of training applications.

The present study examined this emerging technology and the feasibility of applying it to Naval aviation training. The media for four current training programs were surveyed, and detailed cost estimates are presented for equivalent videodisc-based instruction.

Although the cost savings to be realized can be very impressive, the following points should be emphasized - *the microcomputer and videodisc*, particularly when interfaced, possess a wide range of desirable characteristics which can be successfully exploited to the benefit of the training community. However because neither one was developed specifically for the purpose of instruction, an appropriate level of analysis must be performed in order to tap their full potential. The present report represents an important effort in this analysis phase.

ROBERT AHLERS
Scientific Officer

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SECTION I

INTRODUCTION

Naval Air Systems Command/Naval Training Equipment Center (NAVAIRSYSCOM/NAVTRAEQUIPCEN) concern for the acquisition of aviation weapon systems training has resulted in two accomplishments in recent years which are part of the background to this report. First, an instructional systems development (ISD) model, which applies systems logic to curricula development and delivery, was implemented. The ISD model uses state-of-the-art instructional technology to provide cost and training effective development of curricula. Second, procedures were implemented to plan, budget, and manage the training system curricula when using the ISD model.

However, the two sets of procedures must still rely on currently available instructional delivery systems and these systems are major expenses to ISD-based training. Data recorded by ISD program managers indicate that the production and delivery of such training media accounts for about 75 percent of the total resources expended for ISD-based training. The costs involved reflect two components: authoring and production of instruction and life cycle costs of the delivery systems. The study described in this report is an effort to determine the potential for reducing these ISD costs with an Advanced Instructional Delivery System (AIDS) and associated authoring facilities.

With evolutions in electronic and display technologies over the last few years have come the availability of a new generation of instructional delivery system components. A wide variety of relatively inexpensive microcomputer and audiovisual systems have entered a variety of markets. They provide unprecedented capability to individuals and organizations in home, business, and educational settings. Of particular promise as components of AIDS are advancements in optical videodiscs, microprocessors, and computer graphics. While these technologies offer the potential of significantly increased functions for instruction, they also present questions concerning authoring and implementation. Furthermore, the technologies may be combined in a variety of ways to build an AIDS and therefore, design and application trade-offs emerge. A large number of such products and technologies are identified in this report. The information is provided for reporting purposes only, and should not be construed to be an endorsement for any particular manufacturer by either the Navy Training Equipment Center or the authors.

OBJECTIVES

The objectives of the study were threefold:

1) to determine the application of an AIDS within the NAVAIRSYSCOM/NAVTRAEQUIPCEN ISD model for Aviation Weapon Systems,

2) to determine the feasibility of development of an AIDS, and

3) to determine the potential savings gained through development and application of an AIDS.

These objectives were to be viewed within the context of future as well as current ISD efforts. The evolutionary trends in the new technologies will continue in desirable directions of lower cost and user ease. These trends were to be identified for consideration of the future ISD programs.

APPROACH

The approach in achieving the study objectives consisted of five major tasks. First, a survey of current, state-of-the-art media used in ISD-based training for Aviation Weapon Systems was performed. The purpose of this task was to provide data on which to base conclusions about applications, present and future, and costing for comparisons of AIDS versus continuing the status quo. Information was obtained on hardware, software, use, staffing, instructional strategies and other factors. This task provided inputs for satisfying both objectives one and three above.

Second, a concurrent survey of the technology and costs on potential advanced instructional delivery systems was performed. Because the evolution in component technologies is rapid, information pertaining to both the immediate time frame (1978-1979) and several generations through 1985 was collected. This task related to objective two, feasibility of development of AIDS, and objective three for cost comparisons.

The third task was cost comparison of AIDS to the status quo to determine potential cost savings. Primary sources of data came from tasks two and three but had to be analyzed and displayed in meaningful formats. The fourth task was to specify one or more AIDS for the applications identified. The fifth task was related, in that computer programming needed for AIDS development was to be specified. These two tasks, building upon the first three tasks, resulted in specifications for an experimental AIDS with a phased implementation approach.

SUMMARY OF RESULTS

The analysis of current delivery systems indicated that if AIDS were available today, a substantial amount of ground school training for air crew personnel and maintenance training could be delivered with AIDS. More than 50 percent of current ISD-based NAVAIRSYSCOM training (that is, virtually all except trainer and air exercises) could be implemented on an AIDS. In addition, training could be transported to forward deployment sites where training does not now exist by taking advantage of the portability, small space requirements, and low costs of AIDS. By implementation of AIDS, the media selection process may also be impacted. Currently, the ISD model chooses from a traditional media pool. If AIDS is implemented, the media selection procedures could be modified to allow greater flexibility in the selection decision process.

AIDS is feasible to meet the training requirements. The hardware and software will be available shortly. In fact, a family of AIDS, with increasing capabilities, is suggested by the technology trends. The configurations of AIDS provide capability for media production and revision advantages

and are therefore linked to the objective for reduced cost in development of ISD curricula. Special development facilities are also detailed in the report to further reduce development costs.

It is, in fact, the development costs rather than the delivery system costs, that may result in the greatest savings over current delivery system applications. Cost savings projected could be as much as the 25 percent to 75 percent range over current media development.

While the concept of AIDS and associated media development systems offers a strong potential for decreased costs, a caution is in order. AIDS is feasible in concept only today. Most of the AIDS systems discussed exist only as prototype and demonstration models. Data on reliability and full costs is not complete. For this reason, a phased demonstration and implementation plan is recommended in the report. Each phase will allow answers to questions which ensure effectiveness before full implementation.

SECTION II

ADVANCED INSTRUCTIONAL DELIVERY SYSTEM FEASIBILITY

The 1979-80 period marks a time of transition in which the initial components of new instructional delivery system technologies are becoming available. Laser recording techniques, as a prime example, have provided the basis for "optical" videodisc players. The players represent only the first generation of a variety of high-density video and digital data storage products whose distribution costs are already superior to virtually all current media. In addition, the continuing evolution in very-large-scale-integration (VLSI) of electronic components has resulted in a number of advanced microcomputer components. In particular, the 16-bit microprocessor and 64K byte random-access memory chips allow microcomputer systems to perform functions previously reserved for larger systems. Microsystems utilizing these and other new components will be standard items throughout the early 1980s. The increased power of these new stand-alone computing systems will allow relatively sophisticated computer-generated graphics and instructional software to be utilized in student learning stations, minimizing the need for high-cost computer mainframes. Microprocessors and digital techniques have also resulted in more efficient video production and post-production equipment, allowing film-like editing capabilities while requiring less-highly-trained operators, and reduced maintenance. Today's products may be the first steps toward an all-digital television system using the digital videotape and videodisc recorders of the mid- to late-1980s.

The feasibility of advanced instructional delivery systems for Navy air training is dependent on several factors. In this section those factors will be discussed. The factors include the state-of-the-art capability of the new technologies and the trends for the future. We will begin the feasibility discussion by surveying some current efforts related to development of AIDS using some of the new technologies.

RELATED DEVELOPMENTS

The videodisc has attracted a great deal of attention because of its low-cost, mass-distribution economics and its ability to present a wide variety of audiovisual stimuli which until now have required separate hardware delivery systems. Dr. J. Dexter Fletcher of the Defense Advanced Research Projects Agency has noted:

> It may be that the most important feature of videodiscs is not their ability to present vast amounts of separate audio, video, and photographic information cheaply but rather their ability to freely mix digital, audio, video, and photographic information in any conceivable combination. The ability to intermingle these types of information should provide instruction designers with powerful presentation capabilities. An early research priority

should be to determine more precisely how effective these new capabilities for mixed mode presentations will be for instruction.[1/]

Although the first videodisc systems have only recently appeared on the market, there are already a sizable number of research and development programs underway to study the new capabilities. In addition, efforts include investigation of techniques for development of instructional materials and development of training, job aid, and information retrieval systems utilizing microcomputer systems or large computers interfaced to videodisc players. The programs encompass many of the elements discussed in this present report. Before presenting the information pertaining to use of such systems in NAVAIRSYSCOM/NTEC programs, it is advantageous to briefly describe several related programs. The value of these programs is that, taken together, they reduce the uncertainty of implementing advanced delivery systems and therefore increase the feasibility.

Several relevant Department of Defense programs are in progress. The Navy Personnel Research and Development Center (NPRDC) began a multi-year project to investigate authoring techniques and instructional strategies.[2/][3/] Future efforts may include interface of a videodisc player to a computer and study of premastery requirements. Premastery involves all of the activities and facilities necessary before the disc master can be produced. The Army Research Institute for the Social and Behavioral Sciences is emphasizing, in a three year study, the interactive videodisc for instruction and its impact across all of the interservice procedures for instructional systems development.[4/] The Army Training and Doctrine Command is investigating the training

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[1/] J. D. Fletcher. "Videodisc Overview," Proceedings of the Annual Convention of the Association for the Development of Computer-Based Instructional System, Vol. I, San Diego, California, February 27 - March 1, 1979.

[2/] Hurlock, R. E. and Grant, M. Videodisc Training Technology (working paper, P304-813). Navy Personnel Research and Development Center, January 15, 1979.

[3/] Kribs, H. D., Hawkins, W. W. and Mark, L. J.. Development of Instructional Videodiscs using a Microprocessor for Programmed Control of Sequencing and Interaction. Instructional Science and Development, Inc. San Diego, California, February, 1978.

[4/] Bunderson, C. V.. "Study of Application of Videodisc to ISD." Proceedings of Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, February, 1979.

and cost-effectiveness of converting its TEC (training extension courses) materials from the Bessler Cue-See to videodisc.5/6/ Premastering facilities are located at Fort Sam Houston.

In the educational field, interest is high at the National Science Foundation (NSF) and other Federal Government Agencies. NSF has awarded two grants for development of "intelligent videodisc" systems for science education.7/ The program involves adaptation of existing science education materials to a videodisc format with computer-assisted instruction features. Grants have been made to WICAT, Inc. and the University of Utah. The public broadcasting community is also interested in videodisc. It represents another, inexpensive way to distribute the video materials which currently are transmitted to television receivers within limited ranges. KUON-TV, the Nebraska educational television network at the University of Nebraska, is developing several videodisc programs to assess its viability as an alternate distribution form for public broadcasting.8/ The University of Iowa, in partial association with the KUON-TV efforts, is also producing instructional videodiscs.9/

Industry has, in several cases, decided to bypass a research and development phase. General Motors has ordered 11,500 players for use in showrooms throughout the country. Ford Motor Company, Parts and Service Division, is planning the use of discs for technical training and job aids/documentation to service centers nationally. Philip Morris, Inc. is planning to acquire discs as job aids for electrical/electronic maintenance with a view toward mechanical maintenance tasks and other applications later.

5/Holgren, J. E. "Study of Training Effectiveness using Videodisc." Proceedings of Conference on Interactive Videodisc and Media Storage Technology in Education and Training, Society of Applied Learning Technology, Orlando, Florida, February, 1979.

6/McRae, J. L. "Cost Effectiveness of Videodisc in Army Training." Proceedings of Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, February, 1979.

7/"NSF Supports Development of Computer-Controlled Videodisc System for Learning." National Science Foundation News. April 12, 1979.

8/Daynes, R. Personal Communication. University of Nebraska, Lincoln, March, 1979.

9/Brown, B. R. "Videodiscs at Iowa State University." Presentation to the Association for Educational Communications and Technology, New Orleans, February, 1979.

Several organizations are developing systems based on videodisc players and computer systems. These are probably only the first wave of such systems. As will be noted later, the rapid evolutions in the video and microcomputer/ software technologies should foster new generations of systems with progressive enhancements. Two of the leading CAI system manufacturers are working with videodisc players now. Control Data Corporation has interfaced players to its PLATO terminal and will probably offer this capability to PLATO users.10/ Hazeltine, manufacturer of the TICCIT CAI system, has also developed a micro-processor-based videodisc system for TICCIT. In addition, Data Design Laboratories, Hughes Aircraft, and Westinghouse Corporation offer systems which marry videodiscs and microprocessors.11/12/ General Electric, Ordnance Systems, is also exploring the use of a videodisc player on the General Electric Training System, a CAI system. Two other efforts of note may lead toward enrichments of systems at a later time. The National Library of Medicine is developing an "intelligent controller" to interface videodisc players to a variety of computers.13/ Study of videodisc production techniques for mixing video, audio, and digital storage on a single disc is underway. The Massachusetts Institute of Technology has developed a "Spatial Data Management System" for storage and retrieval of visual databases.14/ Computer Corporation of America has a contract with the Defense Advanced Research Project Agency to develop a less costly version for applications such as command and control systems.

10/Mark, H. "Experience in Connecting Videodisc to PLATO System." Proceedings of Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, February, 1979.

11/Walker, C. L. "Computer Controlled Videodisc/Videoplayer System." Proceedings of Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, February, 1979.

12/Harris, A. L. "Report on CE-SIDE (Concept Evaluation - Soldiers Information Delivery Equipment." Proceedings of Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, February, 1979.

13/Ford, W. H. "Videodisc Technology at the Lister Hill National Center for Biomedical Communication." Proceedings of the Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, February, 1979.

14/Donelson, William C. "Spatial Management of Information." Computer Graphics. August, 1978, pp. 203-209.

Many other programs are of general value in increasing the feasibility of such systems for NAVAIRSYSCOM/NTEC efforts by virtue of deriving an increased user's data base. These include special education and handicapped applications, and data storage (the CIA was a prominent buyer of the early systems available).15/16/17/

This short review of related programs is not meant to be comprehensive or all inclusive. Rather, it serves to illustrate some of the issues concerning feasibility that are being investigated and highlights the high-volume of activity necessary to bring the new technology to a generally feasible status, whether for NAVAIRSYSCOM programs or others which may be quite different. In the remainder of this section, specific data on the new technologies is discussed and related to NAVAIRSYSCOM/NTEC programs.

CURRENT STATUS OF VIDEODISC TECHNOLOGY

A growing number of companies are developing videodisc players. Their markets are the home consumer, education, and data storage. Table 1 lists those companies that have announced videodisc systems under development or already available. The technology used in each manufacturer's system determines a great deal of what may be possible for an instructional delivery system. Optical systems use a laser to read data on the discs either by beams transmitted through the disc (called transmissive) or by reflecting the light back off the disc (called reflective). The optical systems have the advantage of freezing on a single frame and random access to each and every frame. These features make it possible to consider the disc for CAI, slide, videotape, and other media replacements. It is the optical systems listed in Table 1 which are most developed and are now being marketed in limited quantities. The capacitance systems seen in Table 1, unlike the optical systems, have a reading component which makes direct contact with the discs. This means a much greater wear factor and the RCA capacitance system does not allow frame random access.

15/vonFeldt, J. R. "Interactive Video Instruction vía DAVID (Digital and Video Instruction Device)." Proceedings of Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, February, 1979.

16//Fox, R. G. "Interactive Visual Image Controlled (Vis-I-Con) Projection System for Vocational Instruction of the Deaf and Handicapped." Proceedings of the Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, 1979.

17/LaGow, R. G. "Instructional Development Related to an Intelligent Videodisc." Proceedings of Conference on Interactive Videodisc and Media Storage Technology in Education and Training. Society of Applied Learning Technology, Orlando, Florida, February, 1979.

TABLE 1. COMPANIES DEVELOPING VIDEODISC TECHNOLOGY

Technology	Company	Market Orientation	Approximate Cost	Projected Availability
Optical Reflective	Magnavox (with MCA and Philips)	Consumer	$ 700	1979
Optical Reflective/ Digital Storage	Magnavox Government/ Industrial Division (subsidiary of Philips)	Data Storage and Education	$3500	1981
Optical Reflective Compressed Audio Option	MCA (with Pioneer Corp.) MCA (with Pioneer Corp.)	Educational/Industrial Educational/Industrial	$2500 $3500	1979 1979-80
Optical Transmissive Compressed Audio Option	Thomson-CSF	Education Education	$2500	1979
Film-Based Optical	Ardev	Consumer and Ecucation	-	-
Capacitance	Matushita	Consumer and Education	-	-
Capacitance	RCA	Consumer	-	-
Holographic	Hitachi	-	-	-
Film-Based Cards	Bell & Howell	-	-	-
Direct-Read-After-Write (DRAW) Disc Recorder/Player	Magnavox Government/ Industrial (subsidiary of Philips)	Data Storage and Education	$50,000	1981
Kodak	-	-	-	-
Xerox	-	-	-	-

Still other systems, listed in Table 1 and under development, include those using holography, film-storage, and read-after-write technologies. These appear to be offerings for the near future and information pertaining to cost and date of availability are not available at this time. There are undoubtedly other random-access, video and data storage systems, which are unannounced, as other manufacturers continue research and development. The market is being recognized by more and more companies as a necessity to being competitive in the future.

Two models featuring different instructional capabilities are expected to be available in 1979 as indicated in Table 1. The consumer model, marketed by Magnavox with joint development by MCA and Philips, will allow choice of either 30-minute discs with the capability of manual single-frame, random-access or a double-sided disc which can play up to two hours of motion video programming but will not have the single-frame access feature. It is intended for the home consumer entertainment market. An educational/industrial (E/I) player model will combine the 30-minute, single-frame access mode with a microprocessor controller. The controller will allow commands to be entered from a manufacturer-provided keypad, or the player can be interfaced to another computer system for control by an instructional program. It is the E/I player that is the base component for systems developed by companies discussed earlier. The microcomputers in the players are of limited capability and must be interfaced to external computer controllers for expanded program control. MCA and Thomson-CSF are both currently marketing E/I systems.

Consumer Videodiscs

The consumer videodisc provides two separate modes of play. One mode allows manual random-access to the 54,000 single video frames without audio or up to 30 minutes of video motion sequences with two channels of audio. A second mode allows straight play of up to one hour of video motion sequences per side, but without the single frame access capability.

The availability of two channels of audio in normal play mode is another unique feature of the videodisc system, and one whose instructional potential is relatively unexplored. Each audio channel can be used independently, or both can be used to provide a stereo capability. A second audio channel would allow remedial feedback to be placed on one channel along with the mainline instructional material recorded on the other, for example. The consumer models, at an estimated cost of $600 to $800, might thus allow storage of slide programs, videotape presentations with audio, or the equivalent of a programmed text without audio. Workbooks, manuals, and other training documents could also be stored, although it would probably be necessary to reformat them due to TV resolution limitations.

The consumer videodisc, however, does not appear to be an optimum system for NAVAIRSYSCOM training for several reasons. First, any still-frame instructional programs using audio such as the slide/tape programs currently used would sacrifice some of the storage economics of the videodisc since the slides would not be recorded as single frames, but rather as repeated video

sequences synchronized with the duration of the audio track. Table 18 in the Cost Savings Section V compares the costs for mastering F-4 aircrew-training slide/tape sequences on the consumer videodisc versus an E/I videodisc with compressed audio for each frame. A significant savings is realized with the E/I player.

The consumer disc has capabilities for manual step-forward, step-reverse and variable speeds of forward and reverse motion. This allows some additional capabilities available beyond those in traditional frame- or motion-oriented delivery systems. However, it remains to be seen whether it is advisable to require the student to conduct detailed interactions with the player controls for these functions, such as entering frame numbers, manually searching forward and back, etc. It may be that basic player control functions are better handled by computer program, thus allowing student attention to be focused on the instructional content.

The long-term reliability and maintenance requirements of the consumer model are also open questions at this point, especially in ship-board or other rugged environments. Only actual experience with the various consumer and educational/industrial players can answer this question. The survey conducted during this study was not able to pinpoint data of any sort concerning such questions. There should certainly be some answers available by early 1980, when up to 20,000 Magnavox consumer players will have been sold for home use.

Educational/Industrial Videodisc

It is clear that any system aimed at the education and training market will have to provide features similar to the MCA and Thomson-CSF E/I systems which are already in use in a number of operations. These two systems provide similar instructional capabilities. Each will allow the storage of up to 54,000 single frames of static graphics or up to 30 minutes of motion sequences with two channels of high-quality audio. Each frame has a digital identification number stored on it which allows callup of the frame manually or under the control of a computer program. Other standard features include variable slow motion forward or reverse, scan forward and reverse, and step forward and reverse. An optional feature expected to be available sometime after the 1979 marketing of the first E/I players is storage of medium-quality compressed audio with individual frames. This is expected to allow from 15 to 30 seconds of audio to be played back with each frame. At present, the videodisc is a read-only medium whose economics are similar to those of stereo records. A fairly substantial fee must be paid each time a new disc is mastered, so that per disc costs for small quantities are higher than those for large runs of thousands or tens of thousands.

Both MCA DiscoVision and Thomson-CSF have a number of prototype and early production models of educational/industrial players presently in use. It is expected that both companies will have production models available in 1979 at a cost of approximately $2,500 as shown in Table 1. The option allowing 15 to 30 seconds of compressed audio to be stored with each frame is expected to be available sometime in 1979-80. This option will cost an

additional $1,000 above the base E/I player cost. It will thus cost around $3,500 for a unit which can provide all the capabilities of existing media while maximizing distribution cost-savings.

The MCA and Thomson-CSF systems differ in several ways. First, the systems differ in their method of signal detection by the laser element. The MCA system uses a rigid disc which reflects the laser signal, while the Thomson-CSF system uses a transmissive system in which the signal is refracted through a transparent floppy disc. The microprocessor controllers on these E/I players also differ. MCA uses a Fairchild F-8 with 1,000 bytes of random-access memory, while Thomson-CSF uses a Motorola 6800 which, at least in the initial prototypes, had no program memory available to the user. The MCA system will also allow storage of digital program code in 1,000 byte chunks at various points on the disc, so that control programs may be stored on the disc. Both manufacturers have recently reconfigured the microprocessor controllers to incorporate the IEEE 488 general purpose instrumentation bus. This allows the players to communicate with up to 14 other programmable instrumentation devices, sending status codes or data to ther components of distributed processing systems. The details of Thomson-CSF's new programming system should be available in 1979. It is expected that its capabilities will be similar to those which MCA has already made public.

With the exception of the Magnavox/Philips/MCA systems (these companies are working together on their consumer model), none of these approaches listed in Table 1 are compatible with each other. Recent standardization efforts have made very little progress. How much of a problem this will be for training is uncertain. It is entirely likely that, at least in the consumer market, two standards will eventually emerge. One of the optical approaches may emerge as a standard by virtue of market dominance. The capacitance system developed by Matsushita Corporation may also become a standard. The latter allows frame random-access features and is already being investigated as a standard by a number of Japanese manufacturers.

Since each manufacturer has incorporated a different microprocessor in its players, different control codes must be sent from the external computer system in order to control each player. Other E/I players under development will doubtless use other microprocessors. It is, in fact, the intention of disc player manufacturers to provide only the players with which others can make total systems. The IEEE interface will facilitate the use of videodisc within larger simulation systems with more complex input and output modules.

The manufacturers will provide a hand-held keypad which allows the remote input of all the basic player functions. A variety of simple keypad input devices could also be configured to enable limited control of specified student responses without giving students access to full control of player functions. The programmability of the basic players, however, is limited to remote control and preprogramming of play sequences. Any extensive interactive branching based on student responses must be handled by a separate controller device. The range of options for computer control of the E/I players is discussed later in this section in the context of microcomputer enhancements.

Since the Magnavox, MCA and Thomson-CSF players are the only systems definitely on the market at this time, the bulk of this report will center on approaches using one or the other of these systems with emphasis on the two E/I players. However, several advanced features of videodisc systems are still being refined in the manufacturers' laboratories. These include use of the disc for digital storage, development of high-resolution 1,000 scan-line discs which could store approximately 15,000 typed 8½" x 11" documents, and development of desk-top recording units which would allow updating of discs but not erasing and re-recording. These developments represent the future capabilities of video technology for an AIDS.

Future Video Storage Technologies

The Magnavox, Thomson-CSF, and MCA players being marketed in 1979 represent only the first wave of products utilizing the massive storage capabilities of optical recording technology. Second-generation video storage technologies, some of which are shown in Table 1, are already under development and hold the promise of greater flexibility and lower costs for the storage component of an advanced instructional delivery system. These second-generation systems include:

1) Updatable optical recorder/players capable of storing 10 billion bits of data,

2) Film-based videodiscs allowing inexpensive in-house mastering and replication,

3) Film-based videocards offering similar capabilities as videodisc but without the necessity for mechanical disc drive mechanisms and at possibly lower player and recorder/player costs, and

4) High-resolution formats for document storage.

There are undoubtedly other technologies and products under development. An important aspect of the future systems is that they will allow in-house recording and/or replication and would overcome the current limitations of videodisc technologies, i.e., lack of updatability and relatively high mastering/replication costs for small volume applications.

Optical recorder/players for digital storage. A number of companies are reported to be developing updatable optical discs for digital storage. While these discs cannot be erased like magnetic storage media, they can be updated using a relatively small recording unit. The most well-documented effort along these lines is that of Philips Data Systems and their American subsidiary, Magnavox Government and Industrial Systems. Their DRAW (Direct-Read-After-Write) systems will allow the storage of around five billion bits of data. The data can be accessed from a track in around 250 nanoseconds, with maximum time for moving from one edge of the disc to the other at around 100 milliseconds. Typical read/write speed is thus 300K bits/second, although speeds of up to six megabits/second have been achieved. According to an article in

Electro-Optical Systems Design, ". . . higher bit rates and densities plus erasable materials can be predicted from the current technology."18/

According to Magnavox, demonstration models of these units are expected to be ready by the third quarter of 1979, and a number of engineering prototypes will be available for purchase by OEM manufacturers by mid-1980. These initial prototypes will cost around $150,000 for the recorder/players and $20,000 for the players; prototype plastic recording discs will initially sell for around $150. Although application areas and marketing mechanisms have not yet been developed, it is estimated that initial market entry recorders/players would sell in the $50K to $60K range. This price would include a significant amount of control electronics, so that costs for the disc drives alone would be a good deal less. Magnavox is also investigating the feasibility of modifying the consumer videodisc for digital storage, resulting in a player costing around $3,500 to $4,000.

The DRAW system, and other optical data recorder/players like it, will offer not only updatability, but also increased flexibility in display and coding formats. One of the limitations of current videodiscs is the limited resolution and bandwidth of the NTSC format. An optical data player would allow choice of RGB or high-resolution displays of the type used in most computer graphics terminals. Also, if breakthroughs are made in video-quality flat screen displays in the next several years, it is possible that a matrix-addressed format, rather than raster-scan, would be required. An optical data player would therefore allow choice of display according to human factors and training requirements, rather than limiting it to the NTSC standard, a format designed for over-the-air home entertainment applications.

Film-based video storage systems. At least two different systems using laser recording on high density film are now under development. Ardev, Inc. of Mountain View, California, is developing a videodisc system using discs made of Kodak holographic recording film. Bell & Howell and Fuji Photo are both developing a film-based videocard system which would give the same capabilities as videodiscs without the bulky disc drive mechanism. Although it is not known at present whether a recorder will be available with the players, the costs of mastering materials are considerably cheaper than those required for current videodiscs, and duplication can be done in-house with inexpensive diazo duplication equipment. These systems not only have a potentially lower cost for players and materials, but they could also be used in premastery production, although the processing turn-around time would make them less desirable than magnetic discs or DRAW systems for initial editing. Even so, the economics of a film medium would allow a relatively large number of trial discs to be produced before a final acceptable master disc is achieved. Market entry dates and costs are presently unknown, although it is expected that Ardev will have demonstration models available in early 1979.

19/"Philips Develops Diode Laser Recorder," Electro-Optical Systems Design, January, 1979, p. 7.

High-resolution videodisc. Both MCA and Philips have indicated that research is being conducted on the feasibility of high-resolution videodisc formats aimed primarily at the document storage market. A possible MCA product may be a 1,000 scan line monochrome format, with the display aspect ratio reversed to approximate the layout of a typical 8½" x 11" typed page. Phil ps personnel have discussed experimentation with a 1,200 line format, which would allow small typeface documents to be reproduced. There are no concrete indications at this time of either price or date of availability. It is unclear whether any manufacturers are looking toward an eventual high-resolution color video system. MCA does not intend, at this time, to experiment with any high-resolution color video formats. It would seem that the principal barriers are economic rather than technical, since the high-resolution video market is quite small at this time. It is possible, however, that the spread of large-screen video projection systems could ultimately create a consumer demand for a higher-resolution television standard. For the foreseeable future, however, it does not appear that the manufacturers will offer a color high-resolution system.

EXTENDING VIDEODISC CAPABILITIES WITH MICROCOMPUTER TECHNOLOGY

Continuing advances in VLSI components are now making possible the design of a variety of inexpensive general-purpose, stand-alone computer systems. At the low end of the spectrum are the first generation home computers, which range from several hundred to several thousand dollars. At the high-performance end of relevance are a number of stand-alone CAI systems designed for specific education and training environments, and which may cost from $10,000 to $40,000. The more inexpensive systems generally make use of general-purpose microprocessors, while the high-performance systems often are built from specially-designed processing modules using high-speed components and innovative computer architectural concepts. In the 1979-80 period, a new generation of 16-bit microprocessors will be introduced. These new systems will extend the software capabilities of microsystems into applications which have until now required fairly expensive minicomputers. With random-access memory still declining in cost at rates of around 30 percent, annually we can expect to see a variety of inexpensive systems with minicomputer capabilities developed in the next two or three years. These new microprocessors will be capable of directly addressing from one to eight million bytes of memory, compared to the typical 65K address limitations of previous systems.

A microcomputer system designed to augment the capabilities of the optical E/I videodisc player could exhibit a rather wide range of capabilities. As noted previously, several companies are in the process of developing videodisc-based systems, augmented with microcomputers, for training or technical documentation storage and retrieval. At present the list would include Hughes' CE-SIDE project for the Army, Data Design Laboratories' System 110, and the Westinghouse WITS system. In addition, it can be expected that virtually every existing computer-assisted instruction system will eventually be extended to allow a videodisc interface. Of particular interest is the National Library of Medicine (NLM) program aimed at developing an intelligent videodisc controller. NLM's goal is a controller which will be user programmable

so that any videodisc system can be interfaced to any computer system with a minimum of effort. The following sections contain a general discussion of various alternatives which current and near-term microcomputer technology can provide for the development of AIDS.

Microcomputer Controller for Videodisc

Although both the Thomson-CSF and MCA-Pioneer systems contain around 1,000 bytes of random-access memory in the microprocessors which are built into the E/I players, a separate microcomputer for instructional program control is necessary for greater flexibility in instructional strategies and in writing and debugging control code. If control programs are to be stored on the discs simply to load the player microprocessor, these must be written in assembly language rather than a high-level language available on a separate controller. Debugging these programs may also be a problem since they will be read-only memory once they are mastered on the videodisc.

In a previous development by Instructional Science and Development, Inc. of interactive videodisc material, it was found that around 2,200 bytes of Motorola 6800 code were required to control 110 frames of instruction. This was a program with fairly simple branching to a few remedial frames. It was developed for Thomson-CSF's prototype programming system which is now being replaced with several additional programming features. With these constraints in mind, we will use the estimate of 20 bytes of control code per frame to illustrate the kinds of additional computer memory which would be needed to develop a more powerful instructional delivery system that can be provided by the E/I videodisc players alone.

A program similar to the F-4 aircrew training Program at the Marine Corps Air Station in Yuma, Arizona would require a total of around 140K bytes to control 7,000 frames of instruction (the estimated number of slides for the program). Given that a typical lesson sequence might run between 40 and 200 frames (the range of current slide/tape programs), a minimum of 4K bytes of program memory should be available for lesson control. Similarly, a floppy disc or other auxiliary memory should probably hold at least one megabyte of storage (50,000 frames x 20 bytes) in order to be able to hold control programs for a full videodisc composed of still frames. Instructional programs offering more powerful strategies than simple multiple-choice input would probably require additional memory capacity. In addition, the use of high-level languages would also affect the memory requirements, although at this time, there is no experience to more precisely define those requirements.

The interfacing requirements for videodisc control are relatively straight-forward. A videodisc interface must translate commands, probably written in a high-level programming language, into the appropriate control codes in Fairchild F-8, Motorola 6800, or other player microprocessor instruction sets. Commands must be passed from main memory to a peripheral device controller, which then directly communicates with the player micro-processor. The main expense in such a system would be RAM and auxiliary memory for storing instructional programs. Input devices could be as simple

as a 10-key pad, a standard ASCII keyboard, or a special student input keyboard designed around the training application.

Increasing the instructional strategy capabilities of the microcomputer system and providing for user ease of programming requires a higher level language and greater processing power. A wide variety of computer-assisted instruction languages, some with interactive graphics capabilities, are becoming available on microcomputers. These include such CAI languages as PILOT, MUMPS, and MICROTUTOR, as well as commonly used high-level languages such as BASIC, PASCAL, or APL. Special languages such as Hughes' PIL and Data Design Laboratories' ALICE are also available.

At the low end are so-called "tiny" language implementations designed for inexpensive home computers. A tiny PILOT, for instance, uses only about 6K bytes of memory for a micro-interpreter. PILOT allows string matching for student responses as well as simpler multiple-choice processing. A system with tiny PILOT could be implemented at little additional cost over a simpler videodisc controller allowing only short key-stroke responses.

Graphics capability on the computer itself may be an important advantage. It is probable that the videodisc could not be used as the total display for a dynamically changing representation of equipment, for example. This may require overlay of computer graphics. Additionally, computer graphics will allow faster and cheaper revision of graphics which may change. More permanent graphics could still be placed on discs.

A full implementation of a high-level CAI type language with even marginally-effective graphics requires a micro-system with increased capabilities. The Terak system, for instance, a stand-alone micro-system which supports UCSD PASCAL and a medium-resolution graphics package, uses a 16-bit Digital Equipment Corporation LSI-11 and 56K bytes of RAM, along with a floppy disc. This system, complete with a monochrome cathode ray tube, sells for around $8,000. A still more sophisticated CAI system being developed by the National Library of Medicine, uses two 8-bit Intel 8080 processors with 64K RAM each to support PILOT and a specially-designed graphics language with capabilities similar to PLATO graphics. This system, which uses a plasma display, will eventually sell for under $10,000 although initial prices will be somewhat higher.

At the high end of current stand-alone CAI systems are advanced architecture devices such as General Electric's GETS, which contain seven separate processing modules supporting plasma graphics, trainee performance monitoring, string processing, and a sophisticated on-line authoring system. These systems, which are currently being used for strategic weapon systems training, cost around $30,000 each.

In addition to systems built specifically for training applications, there are a number of advanced color graphics terminals which can act as stand-alone systems and should be considered for integration with a videodisc player. Some of the color raster-scan graphics terminals which were available

in 1978 are listed in Table 2 to illustrate the state-of-the-art. It is most likely that many graphics terminal manufacturers will develop stand-alone systems incorporating high-level languages like PASCAL, FORTRAN, or BASIC, along with proprietary graphics software. At the most, this would probably add around $4,000 to the price of a terminal, covering the cost of a 16-bit microprocessor, 64K RAM, a floppy disc controller and drive, and software. This estimate is based on the availability of Western Digital's PASCAL Microengine, which includes the above capabilities for an additional $3,500.

TABLE 2. COMMERCIALLY AVAILABLE COLOR RASTER-SCAN GRAPHICS TERMINALS

Manufacturer/Model	Approximate Cost	Comments
Advanced Electronic Design 256	$10K	Includes built-in NTSC overlay capability; Emulates Tektronix 4027
Tektronix 4027	$10K	
Ramtek 6200	$11K	Size 256 Matrix
Chromatics CG	$16K	60Hz refresh incompatible with NTSC format; stand-alone Z-80-based system with floppy disc, 16K program memory, BASIC
Grinnell GNR-27	$12K	Includes cursor, joystick, 8 x 12 video lookup table

Computer-generated graphics are currently being used to reduce media production costs in a variety of design and business applications. Companies such as General Electric's Genigraphics, Dicomed, and Mathematical Applications Group, Inc. (MAGI) have developed systems for producing standard business slides at costs considerably less than those incurred by using a graphics artist. These business slide production systems for the most part produce standard graphics, charts, and other data displays typically required in business presentations. In order to use computer-generated graphics for air training applications, however, graphics software must be used for picture building as well as for presenting standard data display formats. There are a growing number of graphics software packages - available mostly on large computers and time-sharing systems - which might prove cost-effective for use in production of training media. However, since computer graphics may also need to be developed as an interactive component of a stand-alone instructional delivery system, the systems discussed in this section are those which could be implemented on an 8 bit or 16 bit microcomputer system.

Graphics software for stand-alone computer-based systems is currently in a state of transition. While some stand-alone systems do provide some authoring software allowing for graphics development, as discussed above, the majority of existing graphics software packages are designed for 32 bit mainframe computers. Some packages, however, have been implemented on PDP-11 systems, and could probably be easily adapted for the new 16 bit microcomputer systems which will be introduced in the 1979-80 period. These packages, listed in Table 3, are, for the most part, coded in FORTRAN, which has been the language in which most graphics software has been written. While FORTRAN is far from an ideal language with which to develop graphics software, its availability on a variety of computer systems has resulted in its widespread use for the development of portable graphics software.

Recently, however, more efficient and structured languages such as PASCAL and "C" have become popular since programs are easier to write, read, and debug than with unstructured languages like FORTRAN and BASIC. PASCAL, in particular, is being implemented on virtually every microcomputer system currently in use, and may well develop as the standard software system for small computers. The current "turtle" graphics package available with the UCSD PASCAL system is relatively low-powered, but it is likely that more powerful graphics packages will be developed as PASCAL becomes more widely used.

In addition, a number of languages designed specifically for efficient, user-oriented graphics production are now being developed. Some of these "object-oriented" languages, such as the SMALLTALK system developed by the Xerox Palo Alto Research Center, are designed to allow relatively sophisticated graphics to be developed by naive users, thus minimizing the need for specialized programmers. One of the most important features of "object-oriented" languages is the user's ability to define and name graphic objects and modify them by pointing to them using a touch-panel, light-pen, or cursor. The pointing feature also allows object building and modification to take place by pointing to various menus of commands rather than through entering code as in the FORTRAN systems. These features give the user direct access to the objects being created rather than having to use an intermediate programming language whose logical structure may bear little relationship to the real user-object interactions taking place These systems will probably be available in the 1981-82 period. In this timeframe, too, we should expect graphics packages designed to utilize the new stand-alone capabilities made possible by 16 bit microcomputers' extended addressing capacity.

The Association for Computing Machinery's Special Interest Group for Computer Graphics (SIGGRAPH) has devoted a great deal of energy in the past two years toward defining a graphics standard to increase the portability of graphics software. A proposed Core Standard was published in 1977, and a number of implementations, including some on 16 bit machines, have already been developed. SIGGRAPH's Standard Core Planning Committee has developed a three-year time table aimed at developing a final ANSI graphics standard by 1982.

TABLE 3. GRAPHICS PACKAGES FOR 8 or 16 BIT COMPUTERS AVAILABLE IN 1979-80

GPGS (General Purpose Graphics System)	$800	116 FORTRAN routines. Implemented on PDP 11/45.
Tektronix PLOT 10 Interactive Graphics Library (IGL)		FORTRAN routines implemented on PDP 11s for use with variety of Tektronix graphics terminals. Can also be used with AED 256 color terminal similar to SIGGRAPH standard.
DIGRAF (University of Colorado)	$4,000	FORTRAN implementation of SIGGRAPH Core Standard. Currently Level 3, but full Level 4 implementation expected by end of 1979.
Defense Department	Free	SIGGRAPH Core implementation being developed on a PDP 11/70 using "C" and the UNIX operating system. Being evaluated as possible DoD in-house standard.
GPL (National Library of Medicine Plasma Terminal System)	Unknown	Graphics Primitive Language developed for stand-alone plasma terminal using 8 bit 8080 microprocessors. Can be used with various languages, though now exists only with PILOT CAI language. Would require modifications for use with raster display.
PASCAL "Turtle" Graphics, University of California, San Diego	$200	A relatively low-power, medium-resolution graphics package used with UCSD PASCAL software on Terak 8510a stand-alone system using 16 bit microprocessor. Also on Western Digital Pascal Microengine.
SKETCH, Navy Personnel Research and Development Center	Free	Graphics package being developed for NPRDC's Computer-Controlled Multi-Media System, using PDP 11.

The SIGGRAPH Core System has a number of levels of implementation, ranging from output-only capabilities at the lowest level to interactive capabilities, including viewing and image transformations, at the highest level, Level 4. While the lower levels would be sufficient for graphics production videodisc-based AIDS, Level 4, with its ability to support individual image transformations, would probably be desirable for a fully-interactive computer graphics component of an advanced delivery system.

It should be noted that the SIGGRAPH standard, along with most of the packages listed here, is aimed at production of 2-D and 3-D line graphics. More sophisticated software allowing production of 3-D textured, shaded color graphics is also available on more powerful computer systems. Probably one of the most advanced of these is the CHARGE system currently being developed by HumRRO. The CHARGE system uses custom-designed high speed hardware image generators which can create real-time graphics for from one to several hundred terminals.

The graphics production process, of course, can incorporate a variety of computer-generated, photographic, and conventional techniques. It might prove cost-effective in some cases to use a time-sharing system rather than a smaller, dedicated computer, to develop graphics for videodisc. The variety and power of the software would certainly be much greater than that available on a mini- or micro-system. Any software developed for the interactive graphics components of a delivery system, however, would have to take into account the characters of the delivery system's computing system.

POSSIBLE AIDS CONFIGURATIONS

Table 4 lists eight different AIDS configurations which could be developed using various videodisc/microcomputer combinations. Computer graphics and text, whether on a separate display or overlaid onto the videodisc display, may be used for two different purposes: (1) to make interim revisions to the material before a new videodisc is issued, and (2) to allow dynamic, interactive graphics for simulation of cockpit displays, instrument panels, and other response dependent visuals. A prime characteristic which separates configurations 1 - 4 from 5 - 8 is revision capability. With configurations 1 - 4, any changes required of discs will necessitate a new disc master and duplicates each time. Configurations 5 - 8 utilize computer graphics packages and terminals described previously to augment disc graphics. This allows increasing levels of revision capability without a new disc master each time a change is needed.

These eight systems are representative of the kinds of costs and capabilities which can currently be built into an AIDS device; they are certainly not the only designs possible. The full range of possibilities would be closer to a continuous spectrum from the consumer videodisc to quite sophisticated microcomputer graphics/CAI systems. It is also likely that all the cost figures indicated will decline with time; the 1981-82 time period would see costs considerably reduced for virtually all components of the delivery system.

TABLE 4. VIDEODISC-BASED AIDS--CAPABILITIES AND COSTS

Revisions Only by Issuing New Disc

1) Consumer Model

Capabilities - Passive audio-visual programs; programmed instruction still frame with no audio; video with two channels audio student interaction via controls on player. Probably not engineered for constant use over prolonged periods; maintenance/replacement costs correspondingly higher.

Approximate Cost: $700

2) Educational/Industrial Model

Capabilities - Same as consumer plus simple branching strategies available by storing control programs on disc and using 1,000 bytes random-access memory in the player microprocessor; no audio with single frames.

Approximate Cost: $2,500

3) Educational/Industrial Model with Built-In Compressed Audio

Capabilities - Same as E/I model but with medium-quality audio stored on the player with each single frame.

Approximate Cost: $3,500

4) Educational/Industrial Videodisc Player with Compressed Audio; Simple Microcomputer Controller; Mini-Floppy Disc for Program Storage

Capabilities - Allows storage of instructional control programs with more flexibility in processing student inputs than player microprocessor.

Approximate Cost: $6,000

Revisions Aided with Computer Graphics

5) Micro-CAI System plus E/I Videodisc with Compressed Audio; Text and Low-Resolution Graphics on Second Display; Mini-Floppy Disc System

Capabilities - Limited memory, 16K or 32K RAM plus mini-floppy. Similar to System 4 except second display and more program memory is added. Program revisions would be limited primarily to text and extremely simple graphics.

Approximate Cost: $7,000

6) Micro-CAI System plus E/I Videodisc with Compressed Audio; Text and Medium-Resolution Monochrome Graphics on Second Display; Floppy Disc System

Capabilities - 65K bytes RAM plus larger disc system allows more sophisticated control programs and display of text and medium-resolution monochrome graphics on a second monochrome display.

Approximate Cost: $12,000

TABLE 4. VIDEODISC-BASED AIDS--CAPABILITIES AND COSTS (Continued)

7) Same as above (6), but text and graphics overlaid on videodisc image.

   Approximate Cost: $12,000

8) Micro-CAI System plus E/I Videodisc with Compressed Audio; Full video resolution color graphics terminal with built-in NTSC color overlay capability; 8 colors. Sonic digitizer touch panel; 65K RAM plus floppy disc system with 3.5M bytes capacity.

   Capabilities - Revisions could be handled either by graphics frame generated by microcomputer software or by digitizing camera-ready art and storing it on a floppy disc. A 3.5 Megabyte disc could store around 1,750 frames, which would equal around 25% of a 7,000 frame instructional program. The touch sensor would allow "hands on" simulation for part-task procedural training.

   Approximate Cost: $20,000

The various AIDS configurations listed in Table 4 should not be viewed as mutually exclusive; ideally, an ISD learning center could have a number of modular components which could be added on to a basic system as required by training applications. The virtue of the E/I videodisc player, especially with its IEEE general-purpose interface, is that it can be easily integrated into complex systems upporting up to 15 different devices. A more detailed analysis of particular training squadron requirements would, of course, be needed to specify the ideal mix of AIDS configurations. It is also possible that the development of two or three standard AIDS levels would impact the ISD process, leading to different media development procedures targeted for the capabilities of each different AIDS configuration. This would also, of course, only emerge with considerable experience with development of prototype devices and instructional materials.

Since the configurations listed in Table 4 were developed, a new device has been announced which would considerably enhance the ability to develop interim revisions for videodisc-based systems. Valvo, a German affiliate of Philips, has announced a simple device for displaying slides on television monitors; this system uses a charge-coupled device (CCD) chip to interface a slide projector with the television display. If this system proves to be relatively inexpensive, this would allow any revisions to be developed on slides and input to AIDS using a random-access slide projector under control of the same computer program which controls the sequence of videodisc frames.19/

19/ "Simple Method Peristaltic CCDs to Display Color Slides on TV Set," Electronics, March 1, 1979, p. 70.

This device could be used until it was decided to reissue a revised videodisc. The slides prepared as interim revisions could then be used to develop the new filmstrip or videotape used to master the revised videodisc.

The availability of such a device would no doubt considerably enhance the cost-effectiveness of the E/I players, since revisions could be made without requiring a relatively sophisticated computer graphics system. Computer graphics would, of course, be desirable from an instructional strategy standpoint, but that is an issue separate from the need for revision capability.

SECTION III

APPLICATIONS OF AIDS TO NAVAIRSYSCOM TRAINING

A survey of current media usage in NAVAIRSYSCOM/NTEC ISD-based training was performed concurrently with the advanced technology survey. The purpose was to obtain a representative sampling of training and media characteristics which could be matched to the AIDS capabilities described in the previous section.

MEDIA SELECTION

Many of the media in education and training today are used not because they match the instructional requirements, but simply because that media is available from some pool. Furthermore, instruction is often necessarily designed to fit the media that is available. Both media selection and the instructional design of materials could be enhanced with the use of AIDS by reducing these undesirable constraints on ISD teams. Before describing the NAVAIRSYSCOM training surveyed, these more general potential benefits of AIDS will be discussed.

MIL-T-29053, Training Requirements for Aviation Weapon Systems, provides a representative media selection model which was used for most of the ISD efforts surveyed. The introduction of AIDS, with its family of configurations and building block capabilities, could impact the selection results of this model, or any other since the media pool currently used for media selection will change. The selection model now provides for choices from a variety of common media. With the introduction of AIDS the selection could more appropriately be from a particular configuration of AIDS which has the characteristics needed. To illustrate the impact, it is first necessary to review the selection model that is presented in MIL-T-29053.

There are two formal steps to the model. First, each instructional objective is used as an input to the model by answering five questions about the objective. The questions are:

QUESTION 1: What is the level of behavior expected of the student in this segment?

- 1 = familiarization
- 2 = discriminated recall
- 3 = rule-using

QUESTION 2: What level of content is being taught in this segment?

- 1 = familiarization
- 2 = paired associate
- 3 = concept
- 4 = rule

QUESTION 3: Is the minimum critical set of instances the student needs to see small or large?

1 = small
2 = large

QUESTION 4: What is the minimum display requirement?

1 = verbal and/or symbolic and/or static simple pictorial
2 = verbal and/or symbolic and/or static complex pictorial
3 = dynamic pictorial
4 = interactive

QUESTION 5: Is the memorization component of this objective large or small?

1 = small
2 = large

The media requirements for each objective are defined by the answers to these five questions. In the second step, the media requirements are then input to an algorithm, shown in Figure 1. The darkened triangle in the center is the starting point. Each question is answered as it follows in the flow of the algorithm. The result is one of 44 possible media-alternative, terminal points. Rather than a single media being selected at each terminal point, several possible media in functional rank order of preference are selected for each path. For example, Media #44 (in the lower right hand corner of Figure 1) is:

<u>Media #44</u>

First Choice:	CAI
Second Choice:	Random access slide - workbook
Third Choice:	Mediated interactive lecture
Fourth Choice:	Workbook

A third step in the media selection model is not made explicit although it is necessary for any media selection model and is a major consideration in the present study of AIDS. The factor of cost is considered in media selection. In the NAVAIRSYSCOM applications surveyed, each alternative resulting from a particular terminal point in the selection model was evaluated in some way by cost and budget considerations.

Of these three steps in media selection, the last two would be impacted by development and availability of AIDS. The first step, determination of requirements of the media, is not affected. Learning requirements are not a function of delivery systems available. The second step, however, consists of selection of alternative media and is impacted. The third step which may trade cost against the functional ranking of media would also be impacted.

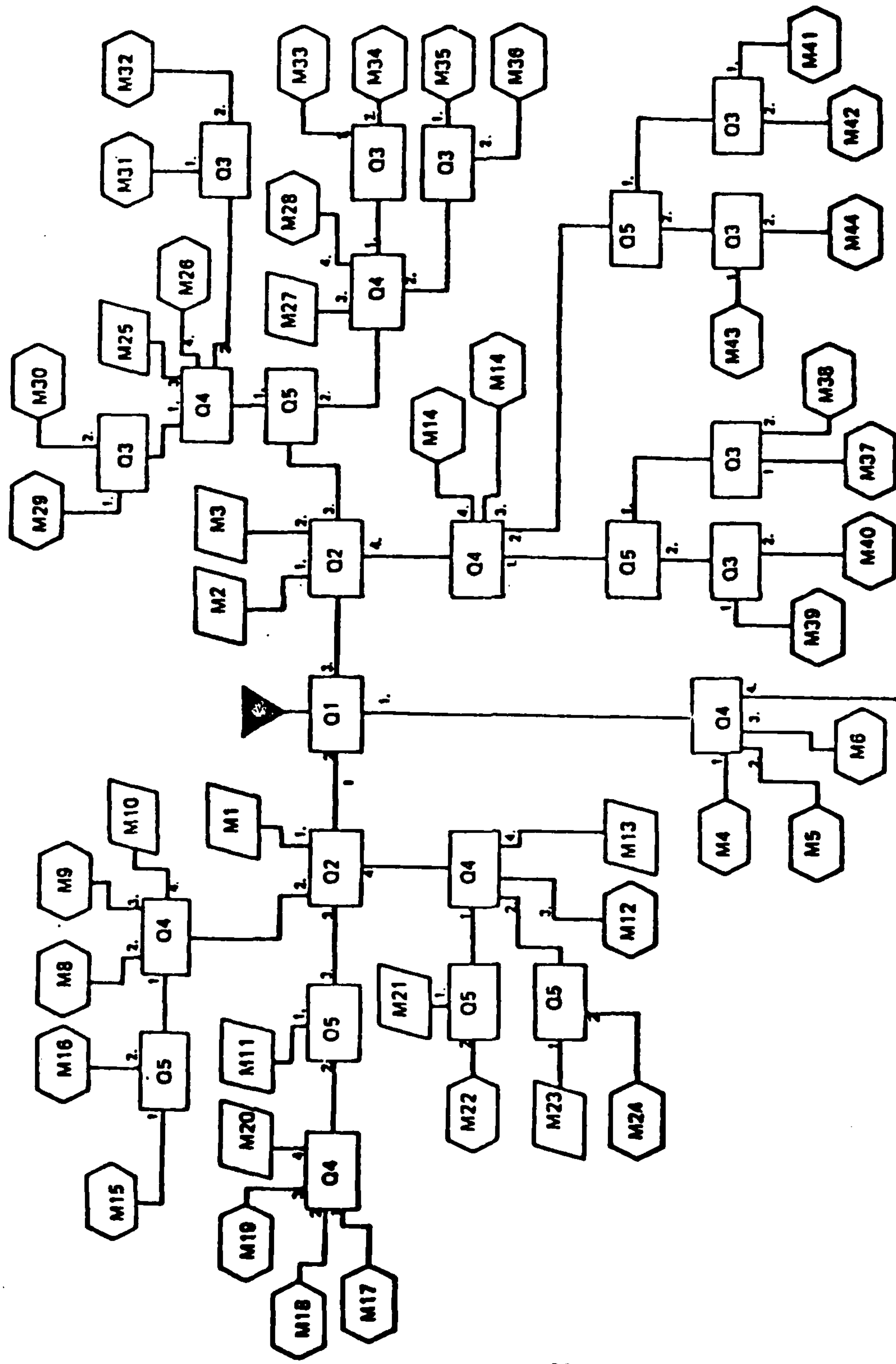


Figure 1. Network Used in Media Selection.

The impact on the second step is that for each representative media type which could be selected in the model, there is an AIDS configuration which could perform the same function. Table 5 illustrates the correspondence. Furthermore, each higher level configuration could perform the functions of all lower level configurations. This means that where a mix of media capabilities is required, the highest level AIDS could be acquired in numbers satisfying the particular training and, time permitting, be used for other lesser requirements as well. To illustrate, assume that the following decisions are made.

Selections		
Media 21	First Choice:	Workbook
	Second Choice:	Mediated interactive lecture
Media 18	First Choice:	CAI
	Second Choice:	Slide-tape
	Third Choice:	Workbook
Media 35	First Choice:	Random access slide-workbook
	Second Choice:	CAI
	Third Choice:	Mediated interactive lecture
	Fourth Choice:	Workbook
Media 40	First Choice:	CAI
	Second Choice:	Random access slide-workbook
	Third Choice:	Workbook
	Fourth Choice:	Mediated interactive lecture

All four of the first-choice media could be implemented on an AIDS configuration. Currently, however, a separate CAI system, a random-access slide projector system, and workbooks would be required. All could be provided for by AIDS and most likely be stored on a single disc. A second factor illustrated by the example is that the cost trade-offs made during selection may change because of AIDS. In the Marine Corps F-4 ISD effort described later in this section, CAI was eliminated as a first choice because of cost. Similar decisions may not be necessary if AIDS are available.

In the remainder of this section, several fleet aviation training systems will be described in terms of the current usage of media listed in Table 5. The application of an AIDS as a replacement for such media will also be discussed. The purpose is not necessarily to suggest that such replacements be made (since current media represent investment costs which would have to be overcome), but to extrapolate to future developments which would be similar to the current training.

SURVEY OF CURRENT TRAINING

In order to determine the type and amount of potential applications for AIDS in the Navy air training community, a survey of current media applications

TABLE 5. CURRENTLY AVAILABLE MEDIA FOR SELECTION IN TRAINING VERSUS POSSIBLE AIDS CONFIGURATIONS

Representative Media Types Cited in MIL-T-29053	Alternative AIDS Configuration*	
a. Mediated interactive lecture	AIDS 1	No interaction, controlled manually by Instructor or Student, responses made on adjunct materials consumer player.
b. Workbook		
c. Slide-tape presentation	AIDS 3	No branching using E/I player with compressed audio.
d. Random-access slide	AIDS 3/4	Random access, program controlled, machine response analysis with microprocessor.
3. Videotape	AIDS 1	Same as above.
(1) Animated		
(2) Full production		
(3) Full production without dramatization		
(4) Single camera production		
(5) Portable edit-in-camera production		
f. Computer-assisted instruction	AIDS 4 - 8	Configuration depends in part on CAI strategies.
g. Hands-on exercises	AIDS 4 - 8	Includes all AIDS 3/4. functions and also provides special interface to response devices, graphics for simulation of equipment.
(1) Student worksheet		
(2) Student evaluation sheet		

* All media types except workbooks and CAI require audio. The AIDS configuration numbers refer to those in Table 4.

was performed. By agreement with the Navy Training Equipment Center technical monitor, it was decided that four current applications would serve as representative. These were:

1) On-going ISD for Marine Corps F-4J Pilots and Radar Intercept Operators at MCAS, Yuma,

2) LAMPS helicopter training exemplified by HS-31 at Naval Air Station, North Island,

3) On-going ISD for the Navy F-14 Air Crew at Naval Air Station, Miramar, and

4) On-going ISD for F-4J maintenance training.

The survey of these applications centered on the type and amount of media currently used. Whether these same applications could be performed by a configuration of AIDS was determined only on the basis of function. Cost will be considered in Section V. The reason cost is not considered in this section is that some applications could prove to be cost-effective if the trends discussed in Section II are realized byt not in the immediate or short-term time frame. By considering each application in two steps, first in terms of functional requirements of an AIDS and only then in terms of cost, we were able to study a progression of AIDS requirements, capabilities, and cost-effectiveness.

An additional type of application was also considered. Trainers, including suitcase trainers, cockpit procedural trainers, and weapon system trainers at NAS North Island and NAS Miramar were also studied. The purpose of trainer study was not to analyze replacement potential of AIDS for the trainers, but to determine if any of this type of training could be performed by AIDS where trainers are not available. The payoff, if any, would be in the implementation of training at affordable cost within space restrictions of ships where none exists now, such as forward deployed carriers.

The following pages address application questions in two parts. First, what current applications could be converted to AIDS and second, what AIDS functional characteristics would be required. The conclusion is that a substantial portion of current applications as well as a variety of additional instructional capabilities could be accommodated by the various levels of AIDS configurations.

MCAS F-4 Training

Table 6 shows the mix of media which has been selected for training of F-4 pilots and radar intercept operators (RIO) at the Marine Corps Air Station at Yuma, Arizona.

TABLE 6. DELIVERY SYSTEMS PLANNED FOR F-4 PILOT AND RIO TRAINING (MCAS YUMA)

Media Selected	Number of Lessons	Number of Segments
Lecture	3	30
Workbook	2	30
Slide/Tape	77	1060
Random Access Slide	12	230
Videotape	1	15
Trainers	89	600
Flight Exercises	293	1500

These media were selected, using the procedures described above, after Objective Hierarchies and Specific Behavioral Objectives were developed. An appropriate instructional medium was selected for each objective in the hierarchy. For this reason, the mix of selected media was taken as appropriate for study purposes and the only question raised was whether an AIDS configuration could fulfill the same media requirements. In some cases, although computer-assisted instruction (CAI) was prescribed by the model, the second appropriate choice was actually selected because of prohibitive costs for CAI. CAI selections being discarded because of high cost would probably not occur if an AIDS were available.

Four of the selected media were not considered for AIDS. These were interactive-mediated lecture, workbooks, trainers, and flight exercises. The lectures, by definition, require a lecturer to be interactive in real-time and this cannot be accomplished in an open question/answer environment by any AIDS configuration in the same manner. Although an AIDS could provide mediated support to the lecture, the major portion of delivery is by instructor. The workbooks require the student to write answers and notes. Students could type answers on an AIDS instead of writing. However, there may be a need to take the media out of the learning center and therefore, workbooks were also eliminated from consideration. Trainers usually were selected to provide greater fidelity than an AIDS will provide. Slide/tape, random-access slide, and videotape lessons were therefore centered on as AIDS candidates. As may be noted from Table 6, these three media account for more than one-third of the lesson segments of the total curriculum and for nearly all of the med a (96%) other than trainers and actual F-4 flight exercises.

Further characteristics of the three media candidates were reviewed in order to match the current media requirements with the feasible AIDS configurations. First is the question of how much storage, of both video and audio information, is needed for AIDS. Second, and of equal importance, was the question of "programmed requirements" (by software or hardware) including branching, student interaction, or student control of sequence and time.

In relation to storage requirements, the slide/tape and random-access slide programs can be expected to range from 6,060 to 8,080 slides. These figures represent 60 to 80 slides per slide/tape program and 120 to 160 slides per random-access slide program. Taking an average, this represents 7,070 slides in the curriculum for these two media. In addition, a 15 to 20 minute audiotape was planned for slide programs, both linear and random-access, representing between 15 to 30 seconds of audio per frame. Discussions with contractor personnel responsible for ISD indicated that 15 seconds or less per frame is the goal during development. For a player with compressed audio, the total amount of storage required for all of the F-4 slide program curriculum represents less than 15% of a one-sided videodisc. The third current media, a videotape lesson running about 15 minutes would fit on the same videodisc and still leave enough room for twice the number of slide programs, with audio, currently planned.

The second question concerns the programmed requirements of the AIDS configuration. For the linear slide/tape programs, there is no interaction. Programs run linearly and each frame is shown at set time durations. Even with a user key to move to the next frame, no special capability beyond a standard E/I player with compressed audio would be required. For the 12 lessons using the random-access slide projectors, however, the student interaction requires response testing and branching capabilities. This requires a programmed capability to accept student inputs, match them against possible answers, and branch to another frame if needed. The programming is relatively simple, however, and again could require only the E/I player.

HSL-31 NAS, North Island

The HSL-31, LAMPS MARK I helicopter training is a fully implemented program at NAS, North Island. A similar program exists at NAS, Norfolk. The media currently used are videotape, slide/tape, random-access slide, workbooks, simulators, and HSL-31 flight exercises. Ground training is provided with two courses. One course is for Pilot/ATOs. A second course is provided for the sensor operator.

Table 7 shows the combined number of programs, by lesson and segment, for each type of ground school media used in the two courses. Trainer and flight exercises were excluded from the survey as requiring greater fidelity than posible on AIDS. Lectures, briefings and debriefings were also excluded because of the requirement for real-time interaction of an instructor with students. The media shown in Table 7 were identified from interviews with HSL-31 personnel and progress records which list each exercise, lesson, segment, and media.

TABLE 7. DELIVERY SYSTEMS IN USE FOR PILOT/ATOs AND SENSOR OPERATORS AT HSL-31 (NAS, MIRAMAR)

Media in Use	Number of Lessons	Number of Segments
Workbooks	106	272
Slide/Tape	47	110
Videotape	12	25
CAI	25	79
Random Access Slide	4	19

Workbooks, although storable on a videodisc if high resolution trends are realized, were again not considered candidates for AIDS because of the need for students to write in them and possibly use them in places other than the HSL-31 learning center. All other media were considered candidates for AIDS. Each segment, as shown in Table 7, represents one learning objective. The total number of segments in use by the remaining candidate media represent almost half of the HSL-31 ground school instructional delivery shown in Table 7.

The storage requirements of the candidate media are shown in Table 8. Each slide/tape program (one segment) averages ten minutes in length with from 15 to 20 slides (20 is used in the calculations). The random-access slide programs were considered, for the purpose of the calculations, to be of the same size as the linear slide/tape programs. CAI programs also were taken to be an average of ten minutes each with 20 frames per segment. Videotape segments also average ten minutes each. The three largest systems (in terms of number of segments) for delivering instruction - slide/tape, random-access slide, and CAI - actually take much less storage than the videotape. Without the videotape only a small portion of one disc would be required. With videotape, ten discs would be required to store all of the media.

TABLE 8. STORAGE REQUIREMENTS FOR HSL-31 LESSONS

	Slide/Tape and Random Access Slide	CAI	Videotape
Number of Videodisc Frames	2580	1580	Approximately 450,000 frames (nine discs)

In terms of student interaction and programming requirements, both the random-access slide and CAI necessitate a configuration to allow student response processing and branching. Compressed audio is also a requirement. Estimates of audio duration per slide were not available although less than 30 seconds per frame is considered reasonable and would therefore be manageable on E/I players with compressed audio.

F-14 Air Crew Training

F-14 replacement air crew training is currently on-going at NAS Miramar. Contractors are developing the instructional programs with VF-124 personnel at NAS Miramar and with monitoring by the Naval Training Equipment Center. The primary users of the instruction are VF-124, NAS Miramar, and VF-101 Component F-14, NAS Oceana. Six other operational squadrons at Miramar and six at Oceana will use the materials to support training.

As is true of the F-4 Marine Corps program described previously, the F-14 air crew training media were selected using the model specified in MIL-T-29053. The results of media selection were reported by Veda Corporation to NTEC (Veda Report Number 53078-77-U/P0025, November 1977). The selection report and discussions with contractor personnel were used to analyze projected current media use.

Table 9 shows the media mix expected upon completion of the current development efforts. As with the previous programs the workbooks and lectures are not considered prime candidates for AIDS. The slide/tape and videotape programs are, however. Each slide/tape program will average 45 minutes with many (the approximate number was not determined during interviews) being two parts. Each part was estimated to consist of 60 slides on an average. Allowing for half the programs to consist of two parts would mean a total of about 9,000 slides. The videotape, having an average duration of 15 minutes each, would require 1.5 videodiscs (for 45 minutes playing time). This would still leave 27,000 available frames for the slide/tape programs, which would therefore be easily stored on the second disc.

TABLE 9. F-14 REPLACEMENT AIR CREW TRAINING MEDIA

Media Selected	Characteristics
Workbooks	One general study, workbooks used with slide/tape programs
Slide/Tape	100 programs, many of them two parts
Videotapes	Three projected
Lectures	With support slides

No student interaction is required during slide/tape or videotape programs other than with associated workbooks. However, it should be noted that the media selection model resulted several times in requirements for CAI which, as was the case for the Marine F-4 efforts, was not an available media. Such requirements could be handled by an AIDS with appropriate programs and microprocessor. In addition, the "interactive" workbooks associated with the audiovisual media may actually be a substitute for what a CAI type AIDS system could do. Compressed audio would also be needed in the AIDS for the slide/tape programs.

Maintenance Training

NTEC also currently has an ISD effort for AN/AWG-10A Aviation Fire Controlman maintenance training at the organizational level. A contractor is developing 27 slide/tape programs and one videotape for this training. The 27 slide/tape program will average 60 slides each; a total of 1,620 slides. The one videotape could be as much as 29 minutes and still fit with the slide frames and audio on one videodisc. No student interaction or programmed branching is expected but compressed audio would be required with an E/I videodisc player.

AIDS in Forward Deployment

As part of the current media survey performed during the study, various trainers, including suitcase trainers for electronic warfare procedures, cockpit trainers, operational procedure trainers, and weapon system trainers, were viewed, and in several cases, actually operated. The trainers are an integral part of advanced training. While it was not anticipated that an AIDS could take the place of the more sophisticated trainers, it was hoped that other potentials for AIDS could be deduced.

The largest gap in training delivery system capability noted in this part of the survey was in the forward deployment of aircraft. In such a situation, the only delivery systems available are the aircraft. Many skills and knowledges may decay during the extended periods of deployment without practice. Trainers, such as those viewed at training sites, cannot be placed on board a ship because of cost, space, and other restrictions. The question then for study was what role could an AIDS play in this training gap. There are two parts to the answer.

First, many procedures which cannot be practiced with actual aircraft for practical reasons or with a trainer for cost/logistic reasons, could be implemented on an AIDS configuration consisting of a videodisc player enhanced by a microprocessor with various response devices. For the air crew, training could be provided on such topics as airways procedures and emergency procedures. For maintenance personnel, training could be provided on emergency procedures, safety, operations procedures, and equipment troubleshooting.

Second, given that AIDS are upward compatible delivery systems, all previous training provided on such media as slide/sound, random-access slide, CAI, and other media could be made available on the system. Given the costs

discussed in Section V and the minimal space required for an AIDS and associated software, the use of AIDS for forward deployment seems desirable. No cost comparison can readily be made against the status quo but the potential benefits for skill maintenance would seem to outweigh any additional costs incurred by implementation of AIDS.

SUMMARY OF AIDS APPLICATIONS

Table 10 summarizes the potential applications for AIDS in the training programs surveyed. A substantial amount of the lessons, the majority of the ground-based media, could be put on a videodisc-based AIDS. In most cases only an E/I player with compressed audio would be required. Where CAI is used, additional microcomputer and program storage would probably be required. The AIDS could take the place of a variety of media devices as seen in Table 10. In addition, storage requirements should be reduced substantially since all of the current media could, in many cases shown, be put on one or two discs.

The implications for the future are fairly clear. If cost is comparable or less, the AIDS configurations would be better than current media. In the next section a major consideration in the cost, material development, will be discussed.

TABLE 10. SUMMARY OF AIDS APPLICATIONS IN REPRESENTATIVE TRAINING PROGRAMS

TRAINING PROGRAMS	MCAS F-4 Pilots and RIO	HSL-31 Pilots/ ATOs, SENSO	F-14 Air Crew	F-4J Maintenance Training	Forward Deployment
CURRENT MEDIA	• Slide/Tape • Random Access Slide • Videotape Programs	• Slide/Tape • Random Access Slide • Videotape • CAI	• Slide/Tape • Videotape	• Slide/Tape • Videotape	None Currently Available
AIDS CON-FIGURATION REQUIRED*	AIDS No. 3, E/I Player with Com-pressed Audio	AIDS No. 4, E/I Player with Compressed Audio and Microcomputer Controller	AIDS No. 3, E/I Player with Compressed Audio	AIDS No. 3, E/I Player with Compressed Audio	AIDS No. 4, E/I Player with Compressed Audio and Micro-computer
NUMBER OF DISCS REQUIRED TO REPLACE MEDIA	One disc could replace all 77 slide/ tape and 12 random access slide lessons (about 7000 slides with tapes) and a videotape.	One disc could replace all 47 slide/ tape and 25 CAI lessons (about 4060 frames com-bined). Nine addition-al discs could replace the 12 video-tape lessons.	Two discs could replace 100 slide/tape programs (about 9000 slides with audio tapes) plus three videotapes and support slides used for lectures.	One disc could replace 27 slide/tape programs (1620 slides with audio tapes) plus one videotape.	Very small storage require-ments compared to standard media.

* As shown in Table 4.

SECTION IV

PREMASTERING PRODUCTION FACILITIES

The primary emphasis of this study was to determine the feasibility of advanced delivery systems. Considerable attention was also paid to systems for AIDS media development. A key question pertains to the requirements imposed by the advanced delivery systems on the media production support facilities. These requirements must be considered in planning for implementation if AIDS are to be feasible. In the case of a delivery system using optical videodiscs, there are a number of alternative production strategies. A survey of components which make up these strategies was performed to configure and cost facilities which would be feasible.

The chief limitation of current videodisc systems is the read-only nature of the medium. Until updatable discs become available, a new videodisc must be mastered each time changes are to be made in the lesson materials on the disc. Current mastering charges by MCA and Thomson-CSF are around $1,000 to $1,250 for a master disc. Replication costs presently vary depending upon quantities desired.

Above and beyond mastering and replication costs are also potentially substantial costs in producing the media required for input to the videodisc mastering process. This is a process separate from disc mastering. We have called it the "premastering" process. MCA currently uses IVC 9000 2" helical machines. The recommended format for frame-oriented material is 35mm motion picture film or broadcast quality videotapes. It remains to be determined whether inputs on 3/4" cassettes or 16mm film will provide an adequate display image for training applications.

The design of premastering facilities for producing these input media is of considerable importance in assessing the feasibility of a videodisc-based approach to an advanced instructional delivery system. These facilities must be used for editing, tryout, and revision of instructional material before producing the final media for input to the videodisc mastering process. There are two general approaches to this problem at the current time. A facility based on slide input and filmstrip output media (for frame oriented materials) could be developed for a comparatively low nonrecurring acquisition cost, but with high recurring costs for photographer, film, and film processing. The film-based approach may also have fewer author capabilities. A second approach based on magnetic videodisc, or other form of electronic still storage, and videotape output would incur higher initial costs but would drastically reduce recurring costs by eliminating the photographic medium except where slides and photographs are required as inputs.

PREMASTERING FACILITY REQUIREMENTS

There are three major functional requirements which premastering facilities must meet for NAVAIRSYSCOM training programs. The requirements are:

1) Playing of audio and visuals (still or motion) for quality check,

2) Testing and debugging of computer programs, and

3) Playing of all elements of the instructional program for evaluation with sample students.

A fundamental requirement is the capability to view the visuals developed on a video monitor for quality control. The premastering facilities must allow input of "raw" video sources. The sources might be camera-ready art, slides, filmstrips, motion picture film, or videotapes. It is necessary to display these visuals on a standard CRT in order to check legibility, color loss, and to ensure that video cutoff has been properly planned for in the graphic development. In addition, the aperture used in developing slides, filmstrips, or other media must match the SMPTE standard being used by videodisc manufacturers in their film to tape transfer. A difference in aperture may result in critical information being lost in the final videodisc frame. Audio sequences, whether or not associated with visuals, must also be tested.

If there are to be branching or other computer-controlled sequences in the instruction, the facilities should provide for testing control of still frame and motion sequences by computer program. This is especially important if part of the instructional control program is to be stored directly on the videodisc, a capability being planned by several manufacturers. Debugging of the control program should be accomplished before the disc is mastered since any extensive changes to the program might exceed the capacity of the target delivery system's microcomputer.

Placing the control program on the disc will also require the premastering facilities' computer to support the instruction set of the target videodisc system's microprocessor--at this point, either MCA's Fairchild F-8 or Thomson-CSF's Motorola 6800. This might be done with either a cross-assembler on a minicomputer or mainframe or via a microprocessor development system. It would be preferable to write the instructional control programs in a higher level programming or authoring language, with a software translation into the final assembly language code. Regardless of the programming mode it would still be necessary to perform final debugging of the code by controlling instructional sequences on a premastering facility.

In addition to providing for the testing of audiovisual materials and computer programs, the facility must provide cost effective capabilities for formative evaluation, as required by MIL-T-29053. The premastering production facility should allow play of the total instructional program with learning events, student responses, and data collection as originally specified by designers/authors.

TWO PRODUCTION FACILITY ALTERNATIVES

The exact design of premastering facilities depends upon the further requirements imposed by the nature of the instructional strategies to be used,

target delivery systems selected, and the production and computer resources already in place and available. It is possible, however, to identify two basic alternatives for premastering facilities and to estimate the costs associated with each. A block diagram outlining components of a film-based facility is given in Figure 2. A diagram of a video-based facility using an electronic frame store and videotape recorders is given in Figure 3.

As can be seen from the diagrams, the core of both facilities is a video system in which various input media can be manipulated under computer control in order to produce a simulation of the functioning instructional videodisc. In addition to the instructional control program, the system CPU may also contain graphics software for production of videodisc frames or the computer-generated overlays which are part of the "high end" AIDS configurations described in Section II. The fundamental difference between the systems, however, is that the film system requires single frame material to be input as slides for ultimate production as a filmstrip (shown in Figure 4), while the video system stores single frames electronically for editing and immediate output to a master videotape (Figure 5). While either facility will allow the previewing and evaluation of film, video, or computer-generated inputs, only the video facility allows the integration of editing, revision, and production functions into a single real-time process.

The advantages and disadvantages of the two approaches are summarized in Table 11. There are six characteristics of the two approaches which should be considered within the context of NAVAIRSYSCOM/NTEC ISD requirements. There are: (1) production of media, (2) time factors for production and evaluation, (3) loss of video quality from generation losses, (4) revision efficiency, (5) system acquisition costs, and (6) media production costs.

The fundamental trade-off involved in selecting premastering facilities is between nonrecurring system acquisition costs and recurring production costs. The film system has the advantage of lower acquisition costs compared to the video facility. In the case of NAVAIRSYSCOM ISD programs, familiar equipment such as random-access slide players and VP2000X random-access videotape players could be integrated relatively easily into a film facility. The disadvantages, of course, are the high costs and long turn-around times involved in every step of a photographic production process.

Since the video premastering facility involves a somewhat more complex and expensive system than the film-based approach, the various components deserve some elaboration at this point. There are three basic components to be considered: the electronic frame store; the computer graphics hardware/software system; and the video system itself including camera, VTR, and editor.

Several commercially available electronic frame store systems are listed in Table 12. Frame store systems differ on a number of parameters, including method of storage (analog or digital), recording format, number of frames stored and read/write time. Generally, the actual recording media are either specifially designed magnetic videodiscs or standard computer disc drives which may or may not be modified to increase read/write speeds. For the

Tryout, Editing, Revision

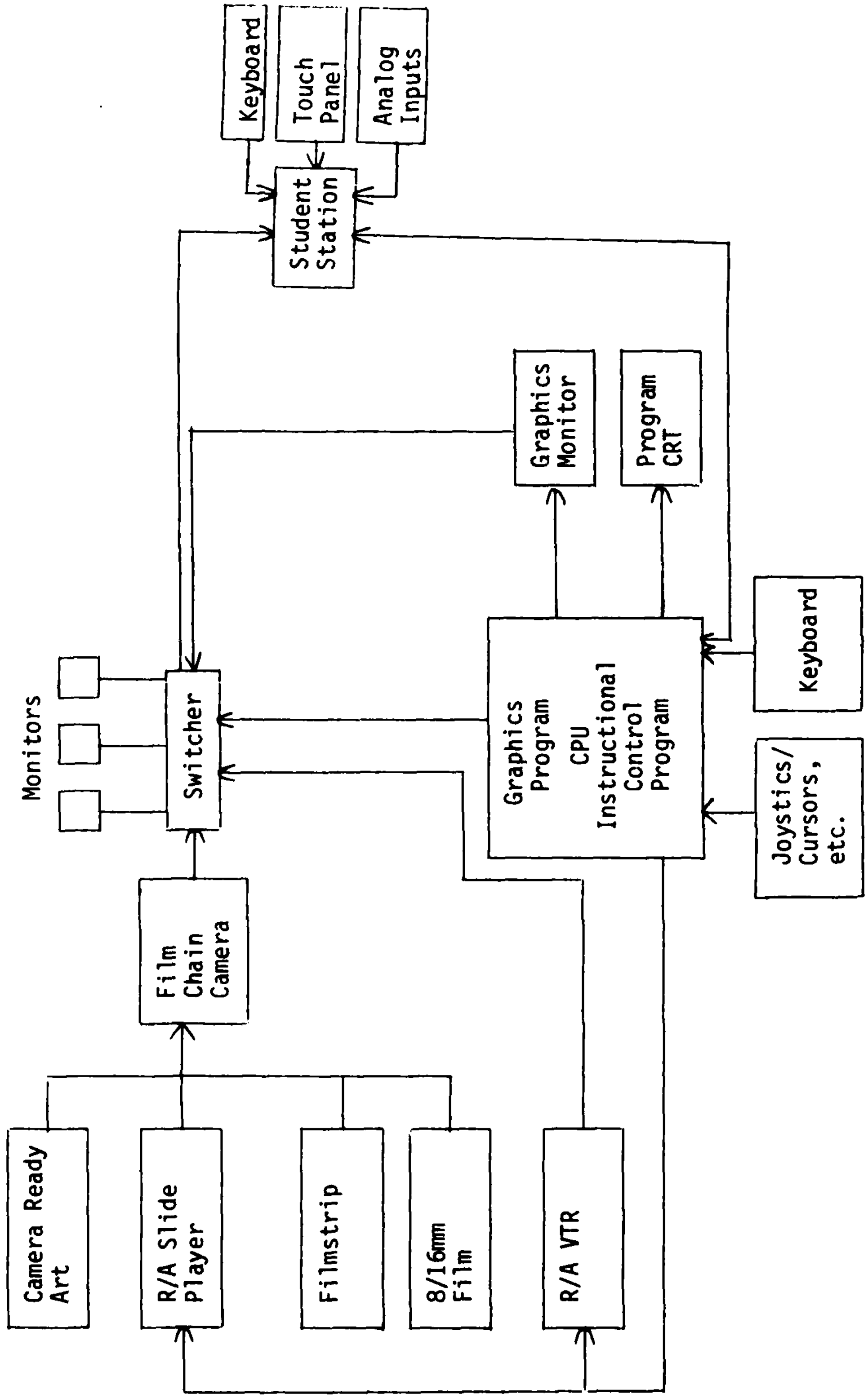


Figure 2. Film-Oriented System

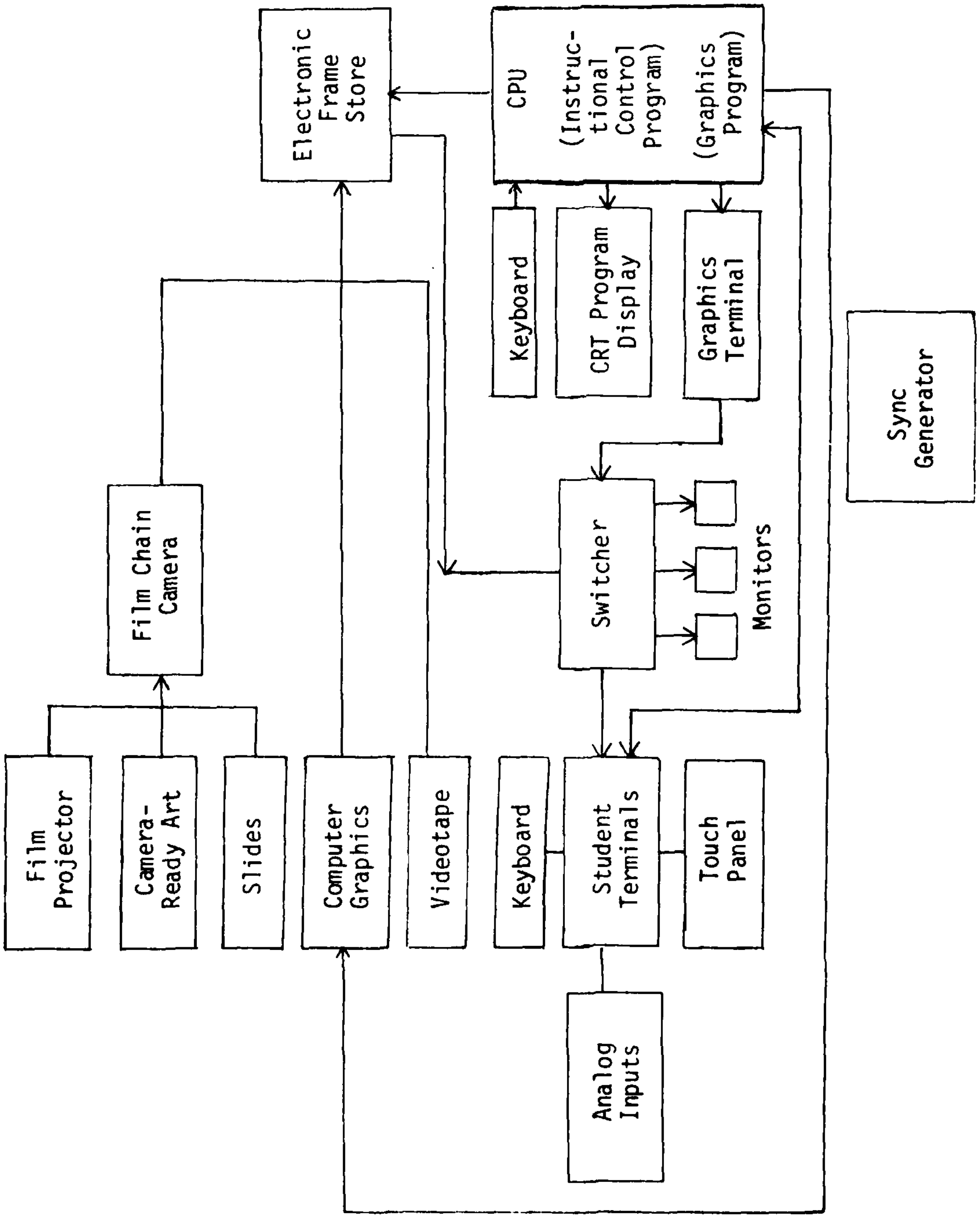


Figure 3. Video-Oriented Premastering System.

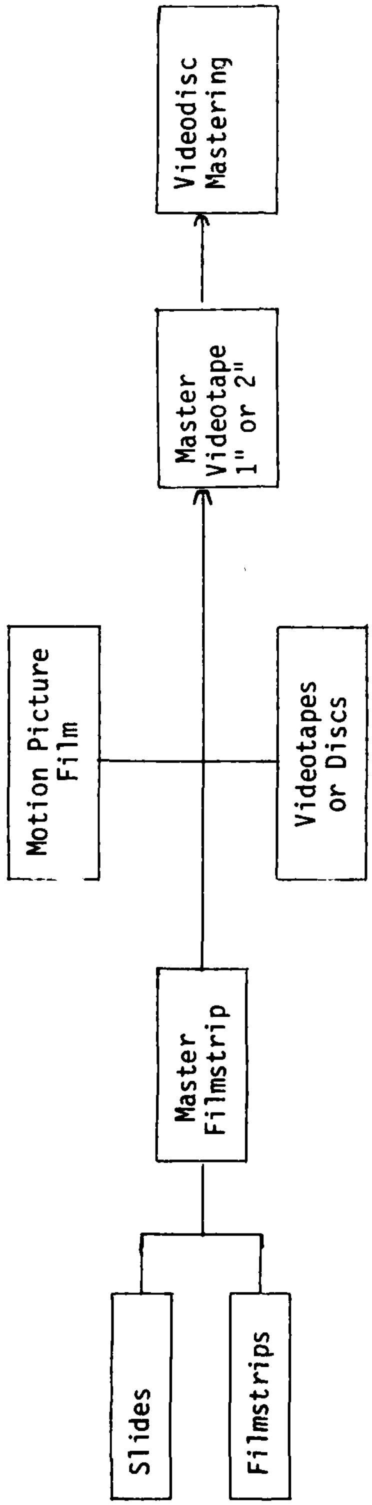


Figure 4. Film-Oriented System Production.

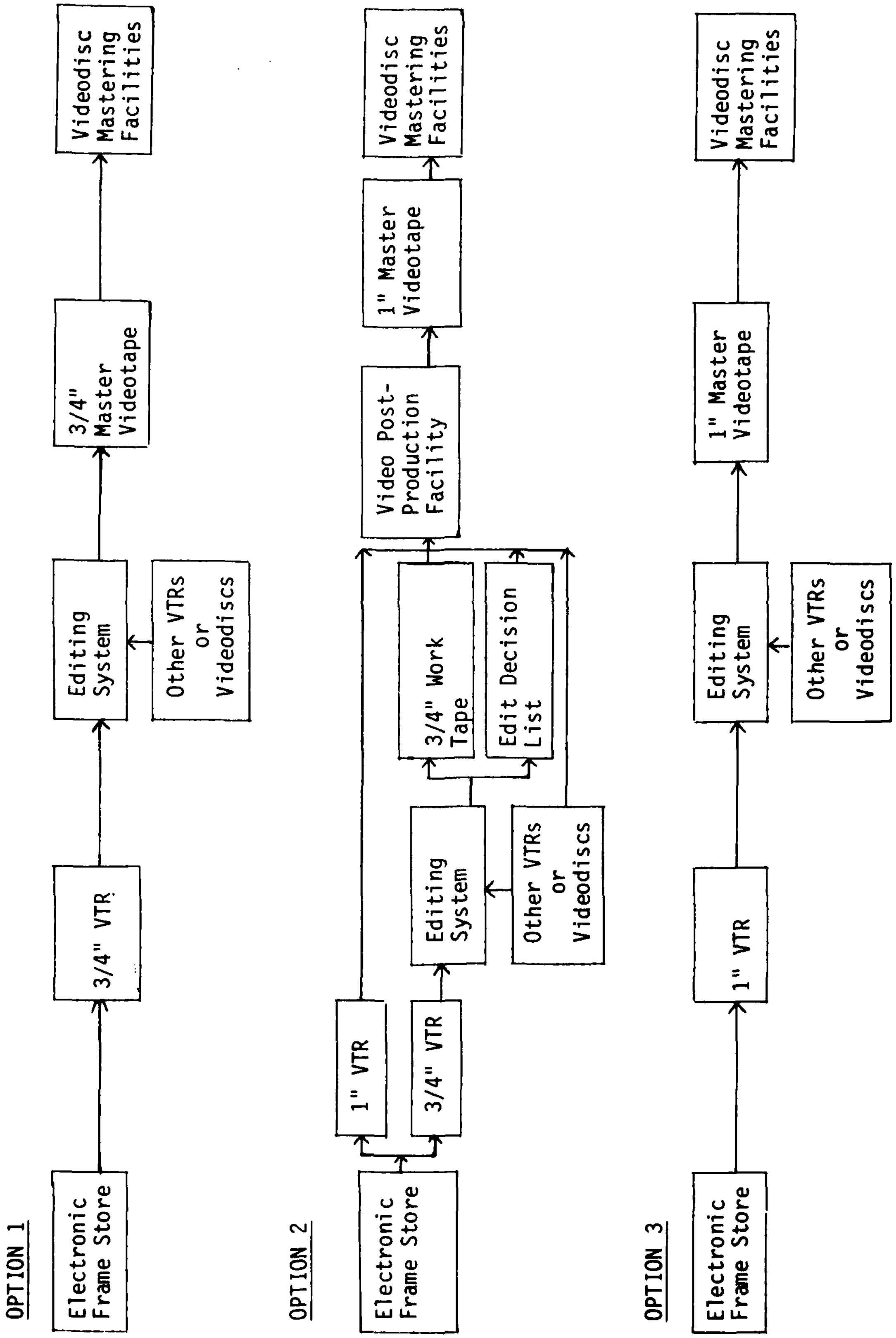


Figure 5. Video-Oriented System Production.

TABLE 11. FILM-BASED AND ELECTRONIC STORAGE PRE-MASTERY FACILITY ADVANTAGES/DISADVANTAGES

Functional Capabilities/Costs	Film-Based Pre-Mastery Facilities	Video-Based Pre-Mastery Facilities
Production	Separate production of slides, filmstrips, and videotape	Total Capability
Time Required	Time lost for separate productions and viewing	No time lost except for any original art required
Generation Loss	Each separate production requires a generation loss Could be several	Eliminates generation loss of film-generated media
Revisions	Complete artwork, photo, slide, filmstrip, revision cycle required	Revisions made in "real-time" during testing
Acquisition Costs	Some equipment already exists in Navy stock. Relatively low cost	Relatively high cost because of hardware acquisition
Production Costs	High Recurring Costs	Eliminates many recurring costs of ISD currently seen

purposes of a videodisc premastering facility, the most important factor is the ability to read and write at a standard video rate, 1/30 of a second. If blocks of several hundred video frames are to be transferred from the frame store to the master videotape, the frame store must be able to output a frame every 1/30 of a second in order to match the speed of the videotape recorder (VTR). This requirement would eliminate some systems such as those offered by Arvin-Echo and ADDA as shown in Table 12. Several low-cost alternatives, such as the Information Processing and Oktel magnetic videodiscs could perform the task.

There are two basic questions which must be considered in the choice of the video system. Since a great deal of instructional material will be still frames, the editing system must be capable of handling a frame-oriented editing code. SMPTE would be one type of time code. The SMPTE time code allows film-style video editing by associating a unique code number with each video frame. Economic revision of the master videotape for videodisc remastering requires a capability to insert or delete single frames or short sequences of frames.

TABLE 12. ELECTRONIC STILL STORE SYSTEMS

Company/Model	Real-Time Write	No. of Frames	Format	Approximate Cost
Arvin-Echo EFS-1A	No (1/15 sec)	400	NTSC/analog	$20,000
Information Processing Systems	Yes	300	NTSC/analog	$28,000
Adda Corp. ESP-100B	No (1/2 sec)	200	NTSC/digital	$46,000
Ampex ESS-2	Yes	814	NTSC/digital	$250,000
Oktel BDR-400	Yes	900	NTSC/analog	$38,000

It would be highly desirable to have this feature during the initial building of the master media also. In addition, microprocessor-controlled editors and VTRs now make it possible to automate the video editing process by developing an edit decision list program which controls both editors and VTRs. Such a capability would considerably reduce the time and personnel needed to produce a revised master videotape. There are a number of such computerized editing systems available, mostly for 1" or 2" VTRs. Convergence Corporation's "Superstick" editing system allows interface of either 3/4" or 1" VTRs and is an example of the flexibility possible.

In addition to SMPTE Code capabilities, a choice must be made between 3/4" and 1" video systems. While 3/4" formats are in wide use for cassette production and distribution, the new 1" helical scan systems offer superior, broadcast-quality performance at around 60% of the cost of 2" quad machines. This difference in quality may prove to be crucial in developing videodisc instruction using complex graphics, although the final determination can only be made as users gain more experience in producing sample videodiscs using both 3/4" and 1" inputs.

The choice of VTR quality also impacts the choice of video cameras for graphics input. Generally, a 3/4" system would make use of a camera with 250 lines horizontal resolution, while a 1" system would require 500 lines resolution to match its performance. Table 13 lists a number of examples of the various elements, along with costs, which might make up one of these video production systems.

TABLE 13. VIDEO PRE-MASTERING FACILITY

	(In Thousands of Dollars)
Option 1--3/4" VTRs	
Computer	30
Electronic Frame Store	28
3/4" VTRs (3)	24
Editing System	12
Video Camera (250 line res.)	6
Switcher	3
Monitors (5-6)	3
Sync Generator	3
Audio System	3
Color Graphics Display	10
I/O Devices	10
Time Base Corrector	17
Wiring, Misc.	4
Total	150
Option 2--3/4" and 1" VTRs	
(final master videotape produced at external post-production facility) using computer edit list developed using 3/4" VTRs	
Same Elements as Option 1, plus 1" VTR	192
Video Camera (500 line res.) approximate cost increase	18
Total	210
Option 3--1" VTRs	
Same Elements as Option 1, minus $24K for 3/4" machines, plus 1" VTRs (3)	252
Video Camera (500 line res.) approximate cost increase	18
TOTAL	270

The use of computer graphics for a stand-alone AIDS was discussed in detail in the section on delivery system feasibility. However, the choice of graphics systems for a videodisc production facility is not confined to the same limitations imposed on a stand-alone delivery system. There are quite a number of computer-based systems specifically designed to develop high-quality production graphics for applications such as flight simulation, scientific research, and entertainment special effects. Two advanced state-of-the-art systems might be mentioned in this context. Ampex, CBS, and the New York Institute of Technology have recently developed a computer graphics/video production facility in New York. HumRRO is developing the CHARGE system, initially for use in flight simulators. The CHARGE system makes use of a high-speed custom hardware image generator which can support several hundred terminals simultaneously. While the cost of the system is relatively high (around $500,000 for the generator and $10,000 per terminal), its possible implementation as a graphics generator for flight simulators suggests that it might also be available in some locations as an input to an AIDS NAVAIRSYSCOM authoring facility.

A particular training facility, then, might in the future possess several different computer graphics systems which could serve as inputs to the premastering facility--in addition to the graphics capability of the AIDS itself. In estimating the costs for this component of the video premastering facility, a figure of $30,000 is projected. This provides somewhat more power than contained in an AIDS device, and, of course, is considerably less than the most advanced systems becoming available. It is difficult at this point to specify more precisely the exact level of computer power which could produce most of the graphics needed for NAVAIRSYSCOM ISD projects. Indeed, that figure might vary from project to project, depending on the nature of the training requirements. The main point to be considered, however, is that a video/electronic frame store system can be interfaced to any existing computer imagery system, and thus can more easily bridge the gap between audiovisual training devices and more complex simulator systems.

FUTURE PREMASTERING FACILITIES

Figure 6 shows the possible evolution of video technology in the future. These capabilities should reduce costs for production even further. The updatable videodisc and videocard systems discussed previously will allow a different approach to premastering when they become available. A digital recording system such as the Philips DRAW recorder/player, for example, would eliminate the need for both the electronic still store and videotape recorders. Even at a cost of $50,000 for a recorder/player, this approach would be cheaper and more flexible than one using a 1" VTR and a magnetic still-store limited to 200 frames. It is also assumed that videodisc mastering facilities by this time will have developed to allow direct recording of distribution videodiscs from a DRAW or other videodisc system.

It has not been determined by manufacturers at this point whether the film-based videodisc and videocard systems will include recorder/players for

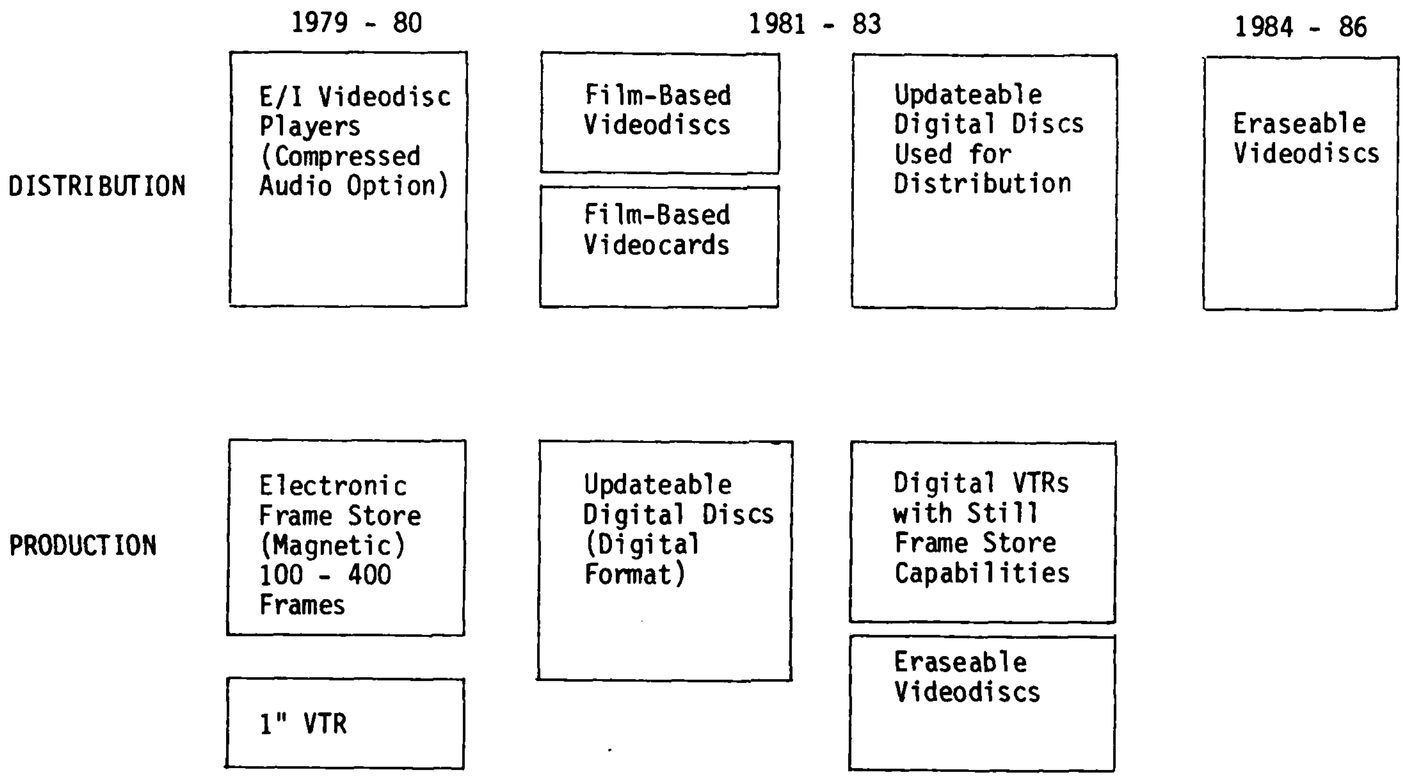


Figure 6. Possible Evolution of Video Technology in the 1980s.

inexpensive in-house master recording. Although not as flexible as an updatable digital disc system, the significantly lower cost realized for disc mastering would make a film-based recorder/player an inexpensive alternative to the magnetic still store/VTR combination. Although there would be additional turn-around time needed for developing each successive master disc, the film-based approach would allow a relatively large number of trial master discs to be produced until an acceptable final product is achieved.

Sometime in the 1984-86 time period, two additional developments may emerge. These are the digital videotape recorder and the erasable video/digital disc. Ampex demonstrated an experimental digital VTR at the February 1979 SMPTE Television Conference. The system, which uses eight magnetic read/write heads, exhibited superior signal-to-noise ratio as well as providing single-frame store capabilities. It is estimated that a successful digital VTR would ultimately be priced somewhere between existing 2" quad and the new 1" helical VTRs. It is estimated that it will be five to seven years before such a product is ready for marketing.

The current manufacturer R&D efforts also suggest the possibility of erasable videodisc systems in the future. A researcher from the University of Toronto announced at the SMPTE Television Conference that he had developed an erasable laser recording technique using an extremely inexpensive recording material. Although reports indicate a great deal of research and development remains to be done, there now seems to be reason for some optimism for eventual availability of fully read/write videodisc systems.

SECTION V

POTENTIAL COST SAVINGS

The desired result from application of the new hardware technology for delivery and development of NAVAIRSYSCOM training is reduced cost with equal or better training. In previous sections specifications for AIDS which could perform NAVAIRSYSCOM training were derived. Since the AIDS could deliver the same training they should, by definition, perform at least equally as well as current media. In this section the cost-effectiveness of AIDS is examined. In order to describe the economics of the new technology a comparison with the current available media is made. Given consideration of proper trade-offs and control of sensitive cost variables, it is concluded that the new technology could substantially reduce costs of development and delivery of training.

COSTING METHODOLOGY

The costs compared are the major elements occurring in the life-cycle of a training delivery system. A work breakdown structure (WBS) was developed to separate the cost elements related to delivery, versus development, of the instructional media. The separation allowed better visibility of cost reduction contributions by new technology.

The WBS cost elements judged to be of major importance for decision makers, given the study objectives, are seen in Table 14. These cost elements do not cover all possible life-cycle costs of a training system. Only those of major importance for comparison purposes of the delivery systems were considered. For example, the analysis phase of ISD is not relevant to the comparison because it will be the same for each alternative costed.

The promise of cost savings for videodisc-based instructional systems has usually been considered to be a function of cheaper distribution, or delivery, of the instruction. This supposition is based upon two characteristics: (1) the multimedia capabilities (only one device would be needed), and (2) the low costs of materials and duplication of discs compared to film, paper, or other media forms. Three major cost elements which test these assumptions were used to compare delivery system costs. As seen in Table 14, these are hardware acquisition, hardware support, and duplication/distribution of media; WBS cost elements 1.0, 2.0, and 3.0, respectively. Each of these costs is associated with the use of advanced technology applied to delivery systems. The costs represent both initial and recurring life cycle costs of a delivery system as noted in Table 14.

Probably the greatest cost of any ISD effort, regardless of the delivery systems used, is that associated with the development of the mediated lesson materials. Previous sections have discussed the videodisc production process using film and video premastering facilities. In addition, the potential of computer graphics for reducing graphics revision costs has been discussed. The WBS elements associated with media development were selected to show the cost impacts of these technology variables. WBS element 4.0 covers the initial production costs. Element 5.0 is intended to include the cost of revising materials during the life of the training system.

TABLE 14. WORK BREAKDOWN COST ELEMENTS FOR COMPARING AIDS AND TRADITIONAL MEDIA

Delivery System Associated Costs

1.0 Hardware Acquisition (Non Recurring)
Includes costs of purchasing systems to specification.

2.0 Hardware Support (Recurring)
Includes costs for operation and maintenance of delivery systems after acquisition.

3.0 Duplication/Distribution (Non Recurring)
Mastering and copying of the initial validated instruction.

Development Associated Costs

4.0 Production (Non Recurring)
The initial development of media from objectives and specifications.

5.0 Revision (Recurring)
Development, duplication, distribution of updates and corrections to training materials.

The costs which were computed for each of the five WBS elements required several trade-offs. For example, the amount of revision capability provided in the delivery system through computer graphics capabilities is of high significance in cost determination. Quicker and cheaper revisions are traded against higher acquisition costs for delivery. Another example of importance is the trade of higher initial costs for a video premastery facility, as opposed to a film-oriented facility, to gain faster, easier, and cheaper production. A major task in the methodology for cost comparison was to identify the trade-offs to be made within each WBS cost element.

A third aspect of the methodology worthy of noting before presenting the data is the use of sensitivity analysis. Some variables have more pronounced impact on the total costs than others. Several cost variables also have ranges which may be possible until more experience is gained. The range and the sensitivity of the bottom line costs within the range were taken into account.

In addition, some costs could not be quantified with confidence and are treated as benefits. "Quicker" turn around times, "faster" revision, and "legibility" are examples. The major cost elements, the rationale for computation, and associated benefit comparisons are discussed in detail below. For purposes of computing dollar values of current media, the Marine Corps F-4 ISD program was used as representative of NAVAIRSYSCOM/NTEC ISD efforts.

COST SAVINGS SUMMARY

Table 15 is a summary of the costs comparing current media, as represented in the F-4 program, and AIDS for the delivery and development WBS elements described above. The details of costing are described separately for each element later in this section. As noted in Table 14, WBS elements 2.0 (hardware support) and 5.0 (revisions) are recurring costs while the other elements are nonrecurring. The hardware support costs were calculated based on a per year figure times a period of five years. The revision costs were calculated on the assumption that 25 percent of the original course would be revised during a five year period. The costs in Table 15 therefore represent a five year life cycle. It was assumed that after five years major changes in equipment or procedures could be possible.

The AIDS used for costing was the E/I videodisc player with compressed audio. As will be detailed later, this AIDS configuration is most economical for purposes of the representative F-4 program. The development costs assume a video-based facility and the use of computer graphics by artists. It is the development costs where the large savings may be potentially greatest. While the duplication/distribution costs of videodiscs seen in Table 15 are cheaper than current slide/based media, the dollar differences are not near as great as they are for production and revision costs.

TABLE 15. COMPARATIVE LIFE COSTS FOR FIVE YEARS OF AIDS VERSUS CURRENT MEDIA ON A REPRESENTATIVE ISD PROGRAM

WBS COST ELEMENT	Cost of Current Media	Cost of AIDS with Video Development
Delivery System Costs		
1.0 Hardware Acquisition	$27,000	$42,000
2.0 Hardware Support	13,500	21,000
3.0 Duplication/Distribution	49,637	1,300
Development Costs		
4.0 Production	322,100	188,200
5.0 Revisions	90,400	52,000
TOTAL	$502,637	$304,500

In summary, the figures in Table 15 show a 60 percent reduction in total delivery system costs. Most of these savings are projected to be the result of using a video-oriented development system rather than gains made by the new technology for delivery systems per se. A note of caution is in order. The costing assumes efficiencies in use of resources for development which should be verified by a testing program such as described in Section VI. In addition, the costs of players and the disc mastering/duplication costs may be increasing at the time of this report and should be monitored.

WBS 1.0, HARDWARE ACQUISITION

Analysis of the Marine Corps F-4 training program (Section III), as well as most of the other training surveyed, indicated that an E/I videodisc player with compressed audio would probably be adequate in place of current media. However, the range of AIDS presented in Table 4 in Section II represents systems whose increased cost is traded for corresponding advantages. Therefore, rather than simply compare acquisition costs of current media with that of an E/I player, a range of AIDS and related costs/benefits should be considered. Table 16 summarizes the trade factors and costs for four AIDS systems and the current media used in Marine Corps F-4 training.

The current media is used as a baseline to compare the AIDS configurations. These media represent all present slide/tape and random-access slide lessons. The cost of current equipment which could be replaced by an AIDS at the F-4 learning center is listed in Table 17. These figures do not include costs for carrels, cabling, video monitors, etc., but rather only include costs for audiovisual equipment which would actually be replaced by an AIDS providing at least equivalent instructional capabilities. Each student station is approximately $2,250. Twelve stations in a learning center would cost about $27,000 as seen in Table 16.

The four AIDS selected for comparison to the baseline are taken from Table 4. These are (1) AIDS number 1 - a consumer model, (2) AIDS number 3 - an E/I model with compressed audio, (3) AIDS number 4 - an E/I player with extended microprocessor capacity, and (4) AIDS number 7 - an E/I player with sufficient microprocessor capability and graphics software to support interim disc revisions and disc overlays. As seen in Table 16, these AIDS have increasing unit costs. The choice of AIDS, however, is not a simple matter of lowest acquisition cost per unit.

Table 16 shows that the videodisc consumer model is at less unit cost than current media and all other AIDS. However, although its media duplication and revision costs are less than current media, it is also the most costly AIDS for these elements. The relative cost differences are detailed in later paragraphs covering the cost elements 3.0, 4.0, and 5.0. Given the increased capabilities of other AIDS for instructional strategies, including emulation of random-access slide programs, the consumer model does not appear to be the best decision. The E/I player with compressed audio was used for cost comparisons in the summary figures above.

TABLE 16. SUMMARY OF TRADE-OFFS AND COSTS IN SELECTING AN ADVANCED INSTRUCTIONAL DELIVERY SYSTEM

	Current Media	AIDS No. 1 (Consumer)	AIDS No. 3 (E/I Model)	AIDS No. 4 (Extended Processor)	AIDS No. 7 (Revision Capability)
Unit Cost	$2,250	$700	$3,500	$6,000	$12,000
Total Cost (12 units)	$27,000	$8,400	$42,000	$72,000	$120,000
Relative Acquisition Costs	Baseline	Less	More	More	Most
Relative Mastery Duplication Costs	Baseline	Less	Less than Consumer	Less than Consumer	Least
Relative Production Revision Costs	Baseline	Less	Less than Consumer	Less than Consumer	Least
Additional Benefits	Baseline	—	Programmable Random Access	Increased capability for instructional settings	Faster revisions Increased capability for instructional strategies

TABLE 17. MARINE CORPS F-4 ISD CENTER MEDIA HARDWARE REPLACEABLE BY AIDS

Hardware	Unit Cost
Sony VP-2000 Video Player, 3/4" U-Matic	$1,237.86
Sony Random Access Retrofit to VP-2000 to Make VP-2000X	200.00
Sony RM-300 Random Access Computer Control	266.50
Howe Rear Projection Module, PM-10	76.05
Telex C-140 USN, Dual Mode Cassette Deck, Player, Ektagraphic Cable, Cat. #94141-001	314.20
Kodak Ektagraphic Slide Projector with 4" Lens, Model AF-1 AV344M, Cat. #100-2088	150.11
UNIT TOTAL	$2,244.72

WBS 2.0, DELIVERY SYSTEM SUPPORT COSTS

The hardware support costs include documentation, any special training for operation or maintenance (if in-house), spares, maintenance personnel, facilities, and operations personnel. A detailed cost breakdown comparing each of these elements for a videodisc-based AIDS versus the traditional slide/tape systems is not possible and probably not of large significance. Little can be determined of the reliability or maintainability of videodisc systems from manufacturers. Several companies with systems and engineering personnel have found no trouble in maintaining parts of their systems. Others, with less skilled personnel, have had more trouble. For present purposes, it has been assumed that prototype system problems will have been resolved and that maintenance costs will be relatively the same as for slide/tape and random-access slide systems. A 10 percent figure (per year of acquisition costs) was used. For a slide/tape system at the MCAS F-4 site this would be $2,700. For an E/I player the costs for maintenance are estimated at $4,200 per year.

Additional benefits would appear to accrue from an AIDS for support requirements. Because of the smaller space needed for storage of discs, less room would be required than for slides and audio tapes. In addition, it might be possible to reduce support personnel required for checking in or out of lessons and caring for the media. The discs also have less wear than slides and are cheaper to duplicate.

WBS 3.0, DUPLICATION/DISTRIBUTION COSTS

Table 18 illustrates the economics for duplication of videodisc versus slide/tape programs. Both the consumer player and the E/I player with the compressed audio option were used in costing videodisc replication. Extending the E/I player with microprocessor and graphics options does not change these costs. Based on data provided by the F-4 training development contractor, mastering and duplication of all training media on 13 two-hour consumer discs would cost 50 percent less than slide/tape duplication. Use of the E/I player, with compressed audio capability, would allow all lessons to be placed on one disc, at a cost of less than 20 percent of the slide/tape duplication.

TABLE 18. DISTRIBUTION COSTS FOR VIDEODISC-BASED AIDS VERSUS SLIDE/TAPE FOR MCAS F-4 TRAINING

Slide/Tape Duplication	Videodisc Duplication (Consumer Model)	Videodisc Duplication (with Compressed Audio)
$49,637	$24,065	$8,405

The F-4 training slide/tape duplication costs were computed based on the present need for 55 duplicates of an estimated 7,100 slides and 77 audio tapes. That is:

a) Slide duplication:

7,100 slides x 55 copies = 390,500 duplicates @ $.10 per slide
= $39,050 for slide duplication, and

b) Audio tape duplication:

77 tapes x 55 copies x $2.50 per duplicate
= $10,587.50 for tape duplication

The Total Slide/Tape Duplications are $49,637.50.

The consumer videodisc usage for slide and audio programs with the F-4 training characteristics would require 13 discs for all lessons. This is because each frame associated with audio must be put on a sufficient number of tracks to be continuously displayed while the audio is played. Total consumer model videodisc costs would thus equal:

a) Filmstrip for Mastery: 7,100 slides x $1 per slide = $7,100

b) Mastery: 13 discs x $1,250 (for mastery) = $16,250

c) Copies: 13 discs x $55 (55 copies at $1 each) = $715

The total consumer disc duplication cost is $24,065 as opposed to $49,637 for slide/tape duplication.

AIDS costs are thus approximately 50 percent of slide/tape duplication; a savings of approximately $25,572, if consumer videodiscs are used.

By using the E/I player with compressed audio, the duplication of slide frames on disc tracks is not necessary and one disc can be used for all media. The total costs of disc mastering and duplication are:

a) Cost of producing filmstrip from slides:
7,100 slides x $1 per slide = $7,100

b) Cost of videodisc mastering and replication:
$1,250 (master) + $55 (55 copies) = $1,305

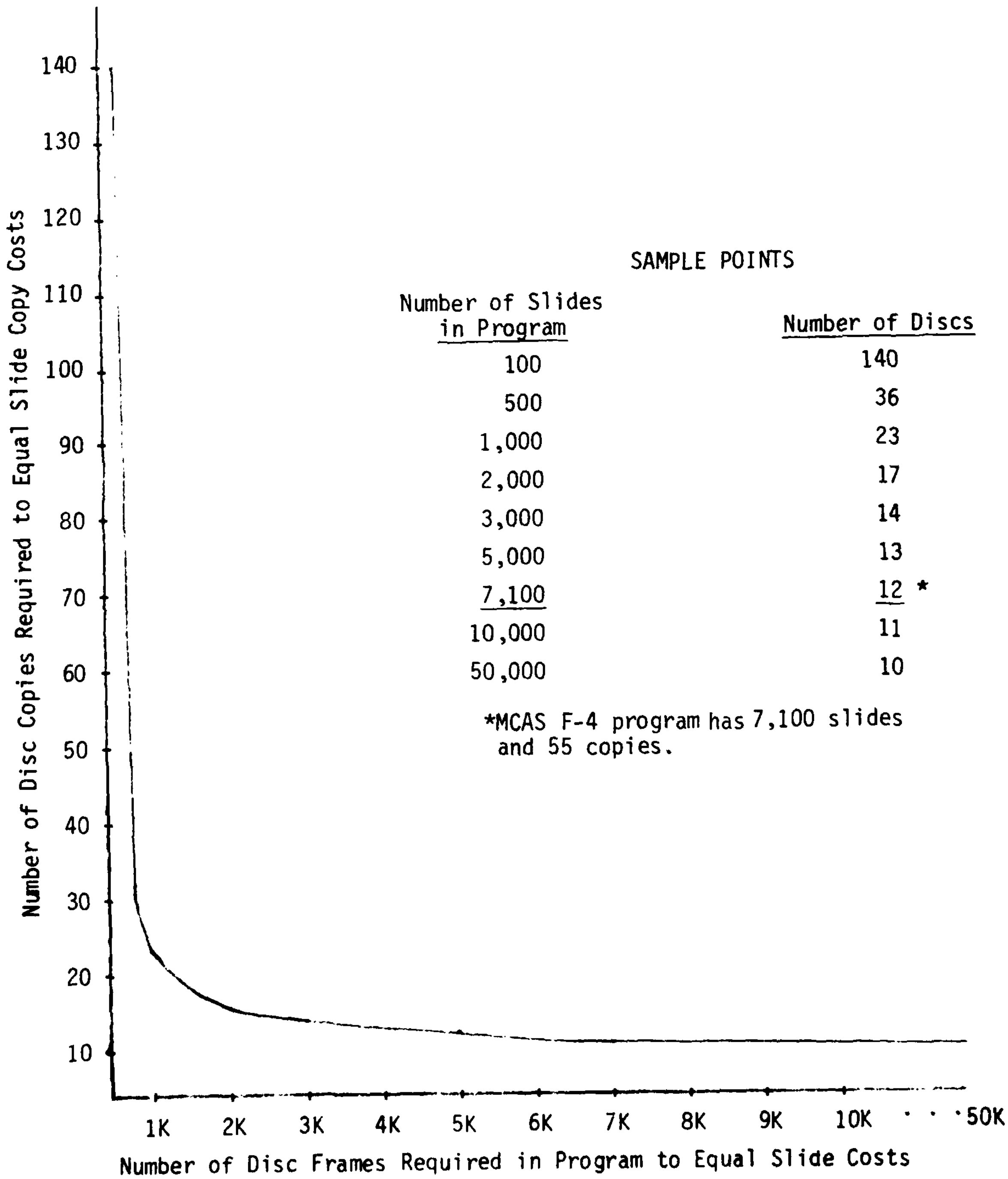
The total cost for one master E/I videodisc and 55 copies with compressed audio is $8,405.

E/I videodisc replication costs are thus 17 percent of slide/tape replication costs. The savings of $41,232 in replication costs would nearly equal the cost of the 12 E/I players with compressed audio which would be required for the F-4 learning center.

Several additional comments should be made on the computations to demonstrate the generality of distribution cost savings allowed by a videodisc-based AIDS. First, videodisc savings increase with the number of total frames stored on each disc, even though the use of a 35mm filmstrip as the disc mastering input adds one dollar per frame to total costs. Disc economics also increase with the total number of disc copies required. Figure 7 shows the break-even point for discs versus slides as a function of the number of frames stored on the videodisc and the number of videodisc copies which will be required. A 1,000 frame program, for instance, must require at least 23 copies for distribution to training centers before videodisc begins to save money over slide program. A 50,000 frame program utilizing almost an entire disc would require only ten copies before savings begin to accrue. An important characteristic of the curve shown in Figure 7 is that as either disc copies or number of frame increases, the curve becomes asymptotic, indicating the cost significance of both functions. A video-oriented premastering production system which eliminated filmstrip costs will reduce videodisc production costs even farther below those used in the figures here. A more detailed discussion of premastering facilities, in the discussion of production costs, indicates the kinds of savings that a video production facility would offer.

WBS 4.0, PRODUCTION

The cost savings for development of instructional materials is realized by using a video premastery facility as described in Section IV. Several sources of savings are probable. First, replacing photographic processes with



SAMPLE POINTS

Number of Slides in Program	Number of Discs
100	140
500	36
1,000	23
2,000	17
3,000	14
5,000	13
7,100	12 *
10,000	11
50,000	10

*MCAS F-4 program has 7,100 slides and 55 copies.

Figure 7. Cost Amortization of Disc Versus Slide Duplication in NAVAIRSYSCOM/NTEC ISD PROGRAMS.

a video-oriented system and electronic frame store will save around $90,000 in a program the size of the F-4 effort. Secondly, using computer graphics to increase the efficiency of the graphic artist provides powerful new tools which could potentially save a large amount also. Finally, the use of the video premastery facility also greatly reduces a major cost involved in issuing new videodiscs; the production of expensive filmstrips. Compared to the expense of producing a new filmstrip, the videodisc mastering and replication fees are small as just seen in the description of duplication costs.

A video production facility would allow the use of computer graphics to develop a substantial percentage of the videodisc lesson materials. Ideally, the AIDS graphics software could be powerful enough to allow most of the videodisc frames to be developed using the AIDS device itself. However, there are a large number of computer graphics packages, in-house and time-shared computer facilities, and graphics production services which could be utilized to develop the original videodisc graphics. These other systems may make it possible to produce more sophisticated graphics at more attractive costs than may be feasible with an AIDS graphics package, especially if a lower-quality AIDS system has been implemented in order to reduce AIDS unit hardware costs.

The kind of premastering production facilities available is a key factor in determining the extent to which computer graphics can be used to produce instructional frames. A video production facility using an electronic frame store and videotape would allow maximum use of computer graphics. A film-oriented production process, with slides and filmstrips could still mix computer-generated graphics, but at potentially less savings in the production process.

Table 19 indicates the costs associated with photographers, paste-up artists, and film/animation cell supplies used in current media production for the Yuma F-4 program. Although it is not assumed that the graphics artist/ photography approach would be entirely eliminated by a video-based facility, it is likely that a significant percentage of production could be handled. The amount saved on production costs would be expected to increase with the sophistication of the user and system. For the purposes of comparing costs for current techniques versus a video-based premastery facility, it is assumed that 75 percent of the current graphic arts/photography process would be handled by computer graphics. If 75 percent of media production used such a video production facility, then over $90,000 in photographer, paste-up artist, and raw materials costs could be saved. These costs would not be incurred at all since the video production system would output videotape directly from the computer-authored materials.

A second major source of potential cost savings, beyond the savings in the photographic costs just described, is through increased efficiency of graphic artists. Current graphic artists cost for the F-4 ISD efforts is estimated to be about $200,000. If 75 percent of graphics production were done with computer authoring of graphics, there would then be $150,000 worth of artist time involved. However, the artist time should be more efficient

with computer graphics tools. How much efficiency can be gained is a difficult question to answer because experience is lacking to provide a basis. Computer-assisted design (CAD) for engineers and architects is sometimes estimated to save about 30 percent in personnel time. Although CAD is not exactly the same capability as is presently of concern, there are common characteristics. If only a 10 percent efficiency gain were achieved, the cost saving would be $15,000. A liberal estimate of 50 percent efficiency would likewise mean a savings of $75,000 in the case of a program similar to the F-4 efforts. For purposes of cost comparison, a 30 percent efficiency factor was used for a cost savings estimate of $45,000.

TABLE 19. PHOTOGRAPHY COSTS ELIMINATED BY A VIDEO-ORIENTED PREMASTERING FACILITY

Source of Cost		Current Media Photography Costs	Cost Savings (75%)
Photographer		$84,436	$63,327
Slide-Tape	$64,372		
R/A Slide	20,064		
Paste-Up Artist		9,090	6,817
Slide-Tape	6,930		
R/A Slide	2,180		
Raw Materials (Film and Animation Cells)		29,088	21,816
$288 x 77 lessons =	22,176		
$576 x 12 lessons =	6,912		
TOTAL		$122,614	$91,960

Table 20 compares production costs of current media in the F-4 effort versus different AIDS configurations using either a film or video premastery facility. As shown in the table, the results indicate that significant savings may be achieved by an AIDS system utilizing a video premastering facility. These figures reflect the savings in photography processes and artist efficiency just discussed. The savings are estimated to be a great deal less for the film-based approach than the video approach. The video approach, using an E/I player, would be about 50 percent of the cost of current media production if the estimates are correct.

TABLE 20. COMPARISON OF PRODUCTION COSTS FOR AIDS AND CURRENT MEDIA
(Costs in Thousands of Dollars)

PRODUCTION COST SOURCES	Present Media 2.3K	Consumer Videodisc 0.7K	E/I Videodisc 3.5K	Micro-CAI 6K	Low Res. Computer 10K	High Res. Graphics 20K
	Delivery System Configurations					
VIDEO-BASED PREMASTERY						
Personnel						
Artist (25% Artist/Illustrator)[2] (75% Artist Programmer)	200	155	155	155	155	155
Photographer [3]	84	21	21	21	21	21
Paste-Up Artist [4]	9.1	2.3	2.3	2.3	2.3	2.3
Instructional Programmer [5]	--	--	--	28.8	28.8	28.8
Supplies						
Slide Film/Animation Cells	29	7.3	7.3	7.3	7.3	7.3
35mm Motion Picture Film	--	--	--	--	--	--
Videotapes	--	0.3	0.3	0.3	0.3	0.3
Duplication						
Slide Duplication	39	--	--	--	--	--
Videodisc Mastering/Replication [6]	--	16.9	1.3	1.3	1.3	1.3
Intermediate Filmstrip	--	--	--	--	--	--
Video Post-Production Services [7]	--	--	1	1	1	1
TOTAL	381.1	202.80	188.2	217	217	217
FILM-BASED PREMASTERY						
Personnel						
Artist	200	200	200	200	190 (8)	187.5(9)
Photographer [10]	84	100.8	100.8	100.8	92.4	88.2
Paste-Up Artist	9.1	9.1	9.1	9.1	8.2	7.8
Instructional Programmer	--	--	--	28.8	28.8	28.8
Supplies						
Slide Film/Animation Cells	29	29	29	29	23.2	20.3
35mm Motion Picture Film	--	0.5	0.5	0.5	0.5	0.5
Videotape	--	--	--	--	--	--
Duplication/Post-Production Services						
Slide Duplication	39	--	--	--	--	--
Videodisc Mastering/Replication	--	16.9	1.3	1.3	1.3	1.3
Filmstrip Production	--	7.1	7.1	7.1	7.1	7.1
Video Post-Production Services [11]	--	1	1	1	1	1
TOTAL	381.1	364.4	348.8	377.6	352.5	342.5

NOTES FOR TABLE 20

1. Assumes Computer Graphics used for 75 percent of Production
2. Assumes that Artist/Programmer and Artist/Illustrator salaries are equal, and that increased efficiency of Artist/Programmer will save 30% of normal production costs (artist/programmer responsible for 75 percent of $200K production = $150K)
3. Assumes 25 percent of production requires Photographer's skills
4. Assumes 25 percent of production requires Paste-Up Artist skills
5. Assumes one person-year at hourly rate of $15.00. Instructional Programmer also responsible for developing edit decision list for videotape editing.
6. Cost is that estimated for 55 discs at eventual cost of $1/disc + $1250 mastering fee. Cost is present (January 1979) manufacturer estimates for low-volume, non-automated videodisc mastering facilities.
7. Only required if Option 2 premastering facilities used.
8. Assumes that up to 20 percent of instruction might be developed on the computer graphics rather than the videodisc component of AIDS. Assumes 30 percent potential savings using computer graphics.
9. Assumes 30 percent of instruction produced by computer.
10. Assumes: (1) photography used for 70 and 80 percent respectively, of production, and (2) production of filmstrip for videodisc mastering will increase photographer requirements by 70 percent.
11. If videotape material is also to be mastered onto videodisc, it may be necessary to transfer film and tape inputs to single master videotape.

The key to these savings, however, lies in the successful implementation of a computer graphics authoring capability. The exact percentage of air training graphics which can be produced with computer-based system, as well as the degree of efficiency of the artist/programmer, can only be determined by more extensive investigation of air training graphics requirements and development of prototype facilities which can generate data on computer graphics production techniques and costs. As noted in Section II, there are a number of suitable graphics packages available now, with even more efficient systems under development for use in the early 1980s, so that there is reason to believe that savings possible in the near term would increase as the more advanced systems become available.

Most of the costs for AIDS in Table 20 are, of course, estimates based on the assumptions described above. The table is intended to illustrate the basic differences between the various configurations rather than to fix a precise estimate on an actual production. It should also be kept in mind that the AIDS systems, especially the high end configurations, offer a great many more instructional capabilities than existing air training media.

Although the production costs illustrated in Table 20 indicated that all AIDS systems show the potential for cheaper production costs than current media, only the video production system can offer a truly significant decrease in media production costs. Production costs across different levels of AIDS configurations are also roughly similar. It is assumed that the more powerful systems will incur additional instructional programmer costs due to more sophisticated, and presumably more effective, branching/interactive instruction. The consumer disc, on the other hand, shows somewhat higher costs for linear instruction compared to the unaugmented E/I player. This is due to the mastering/replication costs for 13 consumer discs which would be necessary compared to only one disc for an E/I player with compressed audio.

WBS 5.0, REVISION COSTS

As can be seen from Table 21, revision costs follow a trend similar to production costs, except that revision costs using a film-based production system are actually higher than revision costs using the existing slide/tape media. This is due to the increased costs involved in developing intermediate filmstrips, which outweigh any savings attributable to videodisc replication versus slide/tape duplicating costs. For video production, however, all AIDS levels result in cheaper revision costs than the existing media. This again is due to reduction of the photography process in premastering, reduction in artist time, and reduction in artist/photographer supplies. The unaugmented E/I player with compressed audio again shows the least costs for revision, although these are mainly attributable to a simpler design of instruction, so that the more sophisticated AIDS configurations would be roughly equivalent if it assumed that the higher costs due to use of an instructional programmer result in more effective training.

When revision costs are added to production costs, it can be seen that AIDS systems using a film-based production system may actually prove to be more expensive than existing slide/tape media. Savings due to inexpensive videodisc mastering/replication may be more than offset by additional expenses in the production of the intermediate filmstrip required for videodisc mastering. The video production system, on the other hand, shows the potential for truly significant savings in both production and revision; the video process actually adds to videodisc replication savings rather than offsetting it.

<u>NOTES FOR TABLE 21</u>

1. Assumes 25 percent of lesson material revised, 75 percent of which uses computer graphics system

TABLE 21. COMPARISON OF REVISION COSTS FOR AIDS AND CURRENT MEDIA
(Costs in Thousands of Dollars)

REVISION COST SOURCES	Present Media 2.3K	Consumer Videodisc 0.7K	E/I Videodisc 3.5K	Micro-CAI 6K	Low Res. Computer 10K	High Res. Graphics 20K
	Delivery System Configurations					
VIDEO-BASED PREMASTERY [1]						
Personnel						
Artist (25% Artist/Illustrator) (75% Artist Programmer) [2]	50	38.3	38.3	38.3	58.2	38.3
Photographer	21	5.3	5.3	5.3	5.3	5.3
Paste-Up Artist	2.3	0.6	0.6	0.6	0.6	0.6
Instructional Programmer	--	--	--	7.2	7.2	7.2
Supplies						
Slide Film/Animation Cells	7.3	1.8	1.8	1.8	1.8	1.8
35mm Motion Picture Film	--	--	--	--	--	--
Videotapes	--	0.1	0.1	0.1	0.1	0.1
Duplication						
Slide Duplication	9.8	--	--	--	--	--
Videodisc Mastering/Replication [3]	--	33.8	3.9	3.9	1.3	1.3
Intermediate Filmstrip	--	--	--	--	--	--
Video Post-Production Services	--	1	1	1	1	1
TOTAL	90.4	80.9	52.0	58.2	75.5	55.6
FILM-BASED PREMASTERY						
Personnel						
Artist [4]	50	50	50	50	57.5	61.3
Photographer	21	25.2	25.2	25.2	25.2	25.2
Paste-Up Artist	2.3	2.3	2.3	2.3	2.3	2.3
Instructional Programmer	--	--	--	7.2	7.2	7.2
Supplies						
Slide Film/Animation Cells	7.3	7.3	7.3	7.3	7.3	7.3
35mm Motion Picture Film	--	0.1	0.1	0.1	0.1	0.1
Videotape	--	--	--	--	--	--
Duplication/Post-Production Services						
Slide Duplication	9.8	--	--	--	--	--
Videodisc Mastering/Replication [5]	--	33.8	3.9	3.9	1.3	1.3
Intermediate Filmstrip	--	21.3	21.3	21.3	7.1	7.1
Video Post-Production Services	--	--	--	--	--	--
TOTAL	90.4	140	110.1	117.3	108.5	111.8

2. Since a two step revision process may take place - medium-resolution interim graphics versus high-resolution graphics videodisc is reissued - the revision costs for the one step revision are multiplied by 1.5

3. The higher cost AIDS allow for interim revisions and thus fewer videodisc reissues. For the other AIDS configurations, it is assumed that three videodisc reissues might be necessary in order to incrporate cumulative revisions equalling 25 percent of original material. For the consumer disc, where the curriculum is stored on 13 discs, it is assumed that 26 disc reissues would represent a reasonable estimate for revisions.

SECTION VI

RECOMMENDATIONS FOR PROTOTYPE DEVELOPMENT AND EVALUATION

The results of this study indicate that several advanced delivery system technologies offer potential for at least the same, possibly increased, instructional effectiveness over current media while decreasing media production costs. The study indicates that all of these technologies will be evolving throughout the 1980s. Each generation should provide less expensive systems with greater power and flexibility.

It is important, however, that such basic questions concerning AIDS specifications, costs, production techniques, instructional effectiveness, user acceptance, and reliability be answered more precisely before any decisions are made concerning widespread implementation of videodisc-based delivery systems in NAVAIRSYSCOM/NTEC ISD programs. In order to more accurately assess the feasibility and the cost-saving potential of the technologies described in this report, it is recommended that a prototype advanced instructional delivery system be developed. In line with the progression of AIDS configurations presented in Section II, the prototype development would proceed in four stages. Each stage is designed to evaluate the feasibility of AIDS configurations with succeedingly more capabilities and greater potential for ISD cost-effectiveness.

The four-phase prototype development program outlined is designed to provide the more precise, detailed estimates of the costs and capabilities required of AIDS and associated production support facilities. It would be possible to combine elements of any of the phases, particularly if other videodisc research and development projects provide answers to important research questions or develop new technology which can be integrated into NAVAIRSYSCOM AIDS. Elements of Phases 1 and 2, for instance, could possibly be combined if any suitable videodisc/microcomputer training systems come to market early in 1980. Similarly, if a system such as the Navy Personnel Research and Development Center's Computer-Controlled Multi-Media System were to be used as part of the prototype development, it might be possible to emulate both delivery and premastering production systems with a relatively small amount of additional hardware. This could possibly allow the evaluation to proceed at a much faster rate. This system represents one of the few existing facilities of the sort described for video-based premastering production.

PHASE 1: EVALUATION OF OFF-THE-SHELF VIDEODISC SYSTEMS

Phase 1 would involve the development of demonstration videodiscs which use existing consumer and educational/industrial videodisc player systems. A selected sample of existing air training lesson materials would be adapted in order to demonstrate the full capabilities of both consumer and E/I players and to determine more accurately the costs and requirements. The results of Phase 1 would provide data for questions such as:

1) Can the majority of existing slide-tape programs be mastered directly onto videodiscs? If not, what kinds of design changes must be made in order to maximize the effectiveness of a video presentation?

2) What are the costs involved in adapting existing non-interactive slide-tape programs to take full advantage of the videodisc's interactive capabilities?

3) What instructional strategies can be supported using only the E/I player microprocessor and digital programs stored on the videodisc itself? What are the programming techniques and costs involved?

4) Can existing print materials such as workbooks, NATOPS manual, and other technical documentation be directly transferred to videodisc and still provide an effective presentation format?

5) What production techniques, film stock and formats, equipment, and post-production services are required to most cost-effectively produce the filmstrip required for input to the videodisc mastering process?

6) How can the videodisc's audio capabilities--two independent channels and, eventually, compressed audio--best be incorporated into the design of instruction?

7) How reliable are the various videodisc systems currently available? What are typical maintenance and spare parts requirements?

8) What impact does use of film, 3/4", and 1" videotape as inputs have on the quality of the final videodisc?

9) What limitations does the quality of the videodisc image place on the development of instructional graphics?

PHASE 2: EVALUATION OF MICROCOMPUTER ENHANCED SYSTEMS

Phase 2 is designed to investigate the requirements for and develop microcomputer CAI systems capable of extending the videodisc's instructional capabilities. Several videodisc instructional sequences would be developed or adapted from existing training materials, and microcomputer control programs would be written using one or two different high-level languages or CAI authoring systems. The size of these programs would then be used to more precisely determine the microcomputer hardware and software needed to handle various instructional strategies. Phase 2 could also investigate the feasibility of using a second display for text and simple graphic revisions to the videodisc material. Phase 2 would give more precise answers to such questions as:

1) How much program memory is necessary to handle a typical instructional videodisc sequence?

2) What are the tradeoffs between storing control programs on the videodisc versus floppy magnetic discs?

3) Which high-level and CAI languages offer the most productive/ least costly programming environments?

4) What kinds of programming aids, e.g. text editors, debuggers, and high-level-language-to-assembly-language translators, are needed to optimize programmer productivity?

5) What are the advantages/disadvantages of using an existing micro-computer system versus designing a system tailored to needs generated by videodisc training material?

6) What are the advantages/disadvantages of using a second display for additional information and revisions? What are optimum display types and sizes?

7) What are the costs involved in implementing various levels of sophistication in student response processing, storage of student historical data, branching decision algorithms or learner control?

8) What are the advantages/disadvantages of using 8-bit or 16-bit CPUs?

9) What kinds of interfaces and student response devices should be included and at what costs?

PHASE 3: EVALUATION OF GRAPHICS FOR DELIVERY AND PRODUCTION

Phase 3 would investigate the requirements for and develop a color computer graphics system capable of overlaying the computer-generated graphics onto the videodisc-stored image. It is expected that existing systems would minimize actual development efforts. A variety of existing computer graphics software packages would be implemented in order to determine which approaches will optimize the productivity of a graphic artist programmer. By developing several instructional sequences, Phase 3 would also investigate the acceptability of the computer graphics/video mix and determine the impacts which this option would have on the design efficiency and effectiveness of instructional materials. This phase would address such questions as:

1) What are the instructional trade-offs between various levels of resolution and their associated costs?

2) What instructional benefits are obtained from such software capabilities as 2-D or 3-D line graphics; shaded and/or textured graphics; and real-time image generation and/or animation?

3) What kinds of programming environments and authoring hardware/ software features will maximize productivity and ease of use?

4) Can the same graphics programs be implemented on different devices with various levels of resolution? If not, how much program revision would be required?

5) Is a mix of computer-generated and videodisc graphics instructionally effective and aesthetically pleasing? What instructional design guidelines are necessary to optimize the effectiveness of this feature?

6) Do existing computer graphics terminals provide all the desirable features for a delivery system or are modifications required to maximize the system's effectiveness?

7) What kinds of student input devices, such as joysticks, touch panels, or light pens, are required to maximize instructional effectiveness:

8) What kinds of microcomputer systems and memory storage are required to implement the various graphics systems being investigated? What are the hardware costs associated with different levels of graphics capabilities?

PHASE 4: DEMONSTRATION OF DELIVERY AND PRODUCTION SYSTEMS

Phase 4 would involve the implementation of a video/electronic frame store premastering facility such as described in Section III. Phase 3 would already have developed the detailed hardware and software specifications for one or more levels of advanced instructional delivery systems. Phase 4 would undertake a fairly substantial development of instruction for evaluation which would be used operationally in a training squadron media center using one or more of the AIDS configurations. Computer graphics capabilities would also be implemented for production of the instruction. The high-end AIDS graphic authoring capability described in Section II would probably be sufficient. Phase 4 is intended to fully develop production techniques for a video pre-mastering facility and collect staffing, cost, and maintenance data associated with such a production system. Since such costs represent the greatest potential savings, Phase 4 would provide the bottom-line results necessary for full implementation decisions.

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6570 AMRL/HE
Wright-Patterson AFB, OH 45433

Headquarters 34 Tactical Airlift
Training Group TTDI
Little Rock AFB, AK 72076

Headquarters
Air Training Command, XPTI
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Randolph AFB, TX 78118

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ASD/YWE
Wright-Patterson AFB, OH 45433

US Air Force Human Resources Lab
AFHRL-FT
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